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PROGRESS IN BIOLOGICAL INQUIRIES 1932

By ELMER HIGGINS

U.S. DEPARTMENT OF COMMERCE
DANIEL C. ROPER, Secretary
BUREAU OF FISHERIES
FRANK T. BELL, Commissioner

PROGRESS IN BIOLOGICAL INQUIRIES
1932

By ELMER HIGGINS

APPENDIX II TO REPORT OF COMMISSIONER OF FISHERIES
FOR THE FISCAL YEAR 1933

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Administrative Reports.—This series contains the annual report of the commissioner and the four divisional reports; namely, "Alaska Fishery and Fur-Seal Industries", "Fishery Industries of the United States", "Progress in Biological Inquiries", and "Propagation and Distribution of Food Fishes." These papers are distributed only as independent octavo pamphlets. However, a general title page and table of contents for each annual series is distributed for the convenience of those who wish to bind them.

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PROGRESS IN BIOLOGICAL INQUIRIES, 1932[1]

By Elmer Higgins, *Chief, Division of Scientific Inquiry*

[With the collaboration of investigators]

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[1] Appendix II to the Report of the U.S. Commissioner of Fisheries for 1933. Approved for publication Apr. 11, 1933.

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INTRODUCTION

Performing the original functions assigned by Congress in 1871 to the old United States Fish Commission, the technical staff of the Division of Scientific Inquiry pursued during 1932 the orderly program of fishery research developed during the past 5 years for the purpose of determining changes in abundance of the food and game fishes of our sea coasts and interior waters, of recommending measures of conservation for the proper protection and utilization of the supply, and of encouraging the farming of aquatic products.

The major scientific projects that have been continued are included in three fields: Marine and fresh water commercial fishery investigations, investigations pertaining to game fishes, and shellfishery investigations. As may be expected from the systematic pursuit of a well-organized research program, progress has been made in the solution of the problems affecting the fisheries in all these fields. It is difficult to select outstanding accomplishments in projects which require many years for completion and which by their very nature develop slowly. Nevertheless, a few may be cited.

From the investigations of the haddock fisheries off the New England coast it is becoming increasingly evident that success or failure of the great trawl fishery, employing nearly 100 of the largest vessels in the fishing fleet, depends upon success or failure of spawning and survival of the young and not directly upon the numbers of spawning adult haddock. The decline of the haddock fishery from its maximum in 1929 to a minimum in 1932 is thus attributed to failure of reproduction in the years from 1926–28. Improvement in the yield is anticipated because of the relatively successful spawning year of 1929 which produced more young haddock than any year since 1924.

Similar censuses of the mackerel population are providing the basis of increasingly accurate predictions in yield of that fishery, and the study of spawning success and survival in the salmon fisheries in Alaska not only provide the basis for the Bureau's regulations of those important fisheries but also yield predictions of future yields that are accepted by the industry in planning fishing and canning operations.

For the first time the mystery which has shrouded the life history and habits of the shrimp on the South Atlantic and Gulf coasts is yielding to scientific research. Although the investigation started as recently as 1931, the extreme vulnerability of the shrimp supply to overfishing has been demonstrated. Because of the fact discovered during the year that the important commercial species have a life cycle limited to about 1 year, warning has been issued to the States that the fisheries should be diligently observed for first signs of depletion, which when it appears will almost certainly run a tragically rapid course resulting in disaster for this extensive industry. The major

features of the life history of the shrimp have been sketched as a basis for wise conservation measures when they are needed.

The oyster investigations of the Bureau have been so designed as to give direct and practical aid to the industry. Experimental and demonstration farms have been established in a number of localities throughout the South Atlantic and Gulf Coast States. More economical and practical methods of opening oysters, which also improve their quality, have been devised, and the Atlantic coast growers have been warned of the dangers to the native stock of the importation of Japanese oysters. These warnings have been heeded, and in some States legislation has been passed prohibiting the planting of the Japanese variety in waters along the Atlantic coast. On the Pacific coast aid has been given to the growers cultivating native Olympia oysters.

During the past few years the Bureau's investigations in aquiculture have been successful in improving hatchery technique, combating disease which annually has taken heavy toll of trout and other game fishes crowded under unnatural conditions in hatchery troughs, and in improving strains of brood fish that are more productive and more disease resistant than wild stock. Continued improvements have been made during the past year in developing diets that will produce growth, vigor, and color in hatchery-reared fish equal or superior to those found in nature. At the same time material economies in operation have been effected by the use of cheaper food materials.

Additional improvements in the restocking of inland waters are resulting from the Bureau's program of stream survey. The extension of highway travel and the rapid increase in the number of anglers have necessitated radical changes in the methods of planting and have demonstrated the necessity for systematic stocking based upon accurate knowledge of conditions of fish life existing in the more accessible lakes and streams. Since the Bureau's responsibility for maintaining and improving angling is definitely indicated in the waters of the public domain, limnological investigations have been concentrated in the national parks and forests in the intermountain region and will be extended to other areas as funds and personnel permit. Studies already made under this program are yielding results in systematic stocking of public waters that will be increasingly apparent to the angler from year to year.

Although funds authorized to be appropriated by the act of May 21, 1930, known as the "Five-Year Construction and Maintenance Program of the U.S. Bureau of Fisheries", have not been provided, the major projects of investigations under way during 1931 were continued. The reduction of appropriations for scientific work which became available July 1, 1932, amounting to more than one-third of the total appropriation, necessitated considerable curtailment of activities in each of the major programs of investigation, and the entire abandonment of several minor undertakings. The steady increase of funds for fishery investigations during the past several years has permitted the gradual expansion of activities and increase in technical personnel. Because of the difficulties in securing well-trained fishery biologists, however, appointments to the permanent staff lagged behind authorized pay rolls and resulted in the employment of a larger number of temporary and part-time assistants than normally would be the case. Hence, the curtailment of funds has resulted first in the discontinuance of virtually all temporary appointments

without seriously reducing the permanent staff. Under the enlarged program of 1931, a great mass of field observations have been collected which during the past year have been subjected to analysis and laboratory study so that reduced expenditure for travel, equipment, and the usual expenses of investigations has not seriously affected the efficiency of the research activities nor materially curtailed the scientific output.

As in former years the Division of Scientific Inquiry participated in the work of the North American Council on Fishery Investigations—an international scientific advisory body composed of representatives from Canada, Newfoundland, France, and the United States, all of which are directly interested in the fisheries of the North Atlantic area. The nineteenth meeting of the council was held in Washington D.C., on October 20 and 21, which a number of the Division's investigators attended in addition to the regular membership of the council.

In previous reports mention has been made of extensive cooperation in fishery research by States and other institutions. Such cooperation has been continued in a gratifying degree during the past year. Not only has official support and encouragement in projects been accorded by the States, but also active participation either by the furnishing of considerable funds or by coordinated activity on the part of the research staffs of the individual State fish and game commissions has been provided to such an extent that activities of the Bureau's staff have been more effective than would have been the case otherwise. Such cooperation which is gratefully acknowledged by the Bureau is in most cases mentioned in connection with the various investigations in the following pages.

PUBLICATIONS

Owing to the curtailed funds for printing the number of publications resulting from investigations of the staff or conducted under supervision of the Division has been reduced. Nevertheless, 12 reports were issued by the Bureau and 34 were printed under private auspices in publications outside of the Bureau of Fisheries. The list of papers published by the Bureau follows:

Fish, Marie Poland.
Contributions to the Early Life Histories of Sixty-two Species of Fishes from Lake Erie and its Tributary Waters. Bulletin, vol. XLVII, pp. 293–398, 144 figs. Bulletin No. 10.

Galtsoff, Paul S.
Introduction of Japanese Oysters into the United States. Fishery Circular No. 12, 16 pp., 4 figs.

Higgins, Elmer.
Progress in Biological Inquiries, 1931. Appendix III, Report, Commissioner of Fisheries, 1932, pp. 441–529.

Hopkins, A. E.
Sensory stimulation of the Oyster, *Ostrea virginica*, by Chemicals. Bulletin, vol. XLVII, pp. 249–261, 11 figs. Bulletin No. 8.

Juday, C., Willis H. Rich, G. I. Kemmerer, and Albert Mann.
Limnological Studies of Karluk Lake, Alaska, 1926–1930. Bulletin, vol. XLVII, pp. 407–436, 6 figs. Bulletin No. 12.

Koehring, V., and H. F. Prytherch.
New Methods of Opening Oysters and Improving their Condition for Market. Investigational Report No. 15, 25 pp., 11 figs.

Pearson, John C.
Winter Trawl Fishery Off the Virginia and North Carolina Coasts. Investigational Report No. 10, 31 pp., 12 figs.

Rich, Willis H.
Salmon-tagging Experiments in Alaska, 1930. Bulletin, vol. XLVII, pp. 399–406, 1 fig. Bulletin No. 11.
Rich, Willis H., and Edward M. Ball.
Statistical Review of the Alaska Salmon Fisheries, part 3: Prince William Sound, Copper River, and Bering River. Bulletin, vol. XLVII, pp. 187–247, 10 figs. Bulletin No. 7.
Rounsefell, George A., and Edwin H. Dahlgren.
Fluctuations in the supply of herring, *Clupea pallasii*, in Prince William Sound, Alaska. Bulletin, vol. XLVII, pp. 263–291, 15 figs. Bulletin No. 9.
Sette, Oscar E.
Outlook for the Mackerel Fishery in 1932. Fishery Circular No. 10, 25 pp., 6 figs.
Surber, Eugene W.
Controlling Vegetation in Fish Ponds with Sodium Arsenite. Investigational Report No. 11, 39 pp., 23 figs.

The following papers were published by members of the staff of the Division of Scientific Inquiry during the year 1932 outside of the Bureau of Fisheries' series:

Davis, H. S.
The Influence of Heredity on the Spawning Season of Trout. Transactions, American Fisheries Society, vol. 61, pp. 43–46.
Deason, Hilary J.
Scientific Investigation of Chubnet Fishing in Lake Michigan. The Fisherman, vol. 1, no. 4, pp. 3–4, 11–12, March 1932.
Firth, Frank E.
Phenominal Development in the Southern Trawl Fishery. Fishing Gazette, vol. 49, no. 12, pp. 6–7.
Galtsoff, P. S.
The Life in the Ocean from a Bio-chemical Point of View. Journal, Washington Academy of Science, vol. 22, no. 9, pp. 246–257.
Spawning Reactions of Three Species of Oysters. Journal, Washington Academy of Science, vol. 22, no. 3, pp. 65–69.
The Coral Reefs of the Hawaiian Islands. The Collecting Net, vol. VII, no. 2, pp. 29–30.
Galtsoff, P. S., and R. O. Smith.
Stimulation of Spawning and Crossfertilization between American and Japanese Oysters. Science, vol. 76, pp. 371–372.
Ginsburg, Isaac.
A Revision of the Genus Gobionellus (Family Gobiidæ). Bulletin, Bingham Oceanographic Foundation, vol. 4, art. 2, 51 pp., 7 figs., March 1932.
Herrington, Wm. C.
The Haddock Catch, What is Happening to It? Fishing, vol. XII, no. 8, pp. 4–5.
An Otter-Trawl Development for Saving Small Fish. Fishing Gazette, vol. 49, no. 4, pp. 8–11, 20.
Herrington, Wm. C., and D. Merriman.
The Advantages of the New Savings Trawl. Fishing Gazette, vol. 49, no. 10, pp. 8–10.
Higgins, Elmer.
Lobster Conservation Demands Protection for the Big Egg-Producers. Fishing, vol. XII, no. 1, January 1932, p. 18.
Fishery Research by the Federal Government. The Collecting Net, July 2, 1932, vol. VII, no. 2, pp. 29–32.
Federal and State Investigation of the Shrimp Progresses. Louisiana Conservation Review, vol. II, no. 11, pp. 30–33, October 1932.
Hildebrand, Samuel F.
On a New Cyprinoid from South Dakota. Journal, Washington Academy of Science, vol. 22, no. 9, pp. 258–260, 1 fig.
On a Collection of Fishes from the Tuckaseegee and upper Catawba River Basins, N.C., with a Description of a New Darter. Journal, Elisha Mitchell Scientific Society, vol. 48, no. 1, pp. 50–82, 2 figs., 1 plate.
Growth of Diamond-back Terrapins, Size Attained, Sex Ratio, and Longevity. Zoologica, vol. IX, no. 15, pp. 551–568, 2 plates.

HILE, RALPH.
Fish Scales and Commercial Fisheries. The Fisherman, vol. 1, no. 10, pp. 3–4, 10, September 1932.
HOPKINS, A. E.
Chemical Stimulation by Salts in the Oyster. Journal, Experimental Zoology, vol. 61, pp. 13–28.
JOBES, FRANK W.
Deep Trapnets on Lakes Huron and Michigan. The Fisherman, vol. 1, no. 3, pp. 3–4, February 1932.
MCMILLIN, H. C. and P. BONNOT.
Oyster Pests in California. California Fish and Game, vol. 18, pp. 147–148.
NEEDHAM, P. R.
Distribution of Bottom Foods in Trout Streams. Field and Stream, February 1932.
Giving Anglers Real Sport. American Game, May–June 1932.
SURBER E. W.
Sodium Arsenite for Controlling Submerged Vegetation in Fish Ponds. Transactions, American Fisheries Society, vol. 61, pp. 143–147.
SURBER, E. W., and O. L. MEEHEAN.
Lethal Concentrations of Arsenic for Certain Aquatic Organisms. Transactions, American Fisheries Society, vol. 61, pp. 225–239.
VAN OOSTEN, JOHN.
The Maximum Age of Fresh-water Fishes. The Fisherman, vol. 1, no. 11, pp. 3–4, October 1932.
Experiments on the Mesh of Trapnets on Lake Erie. The Fisherman, vol. 1, no. 12, pp. 3–4, 8, November 1932.
Review of Great Lakes Work Conducted by the U.S. Bureau of Fisheries. The Fisherman, vol. 2, no. 1, pp. 3–4, 8, December 1932.
WEYMOUTH, F. W.
Federal and State Cooperative Shrimp Investigation in Louisiana. Louisiana Conservation Review, vol. 2, no. 9, pp. 39–40. June 1932.
WIEBE, A. H.
Notes on the Exposure of Several Species of Fish to Sudden Changes in the Hydrogen-ion Concentration of the Water and to an Atmosphere of Pure Oxygen. Transactions, American Fisheries Society, vol. 61, pp. 216–222.
WIEBE, A. H., E. G. Gross, and D. H. Slaughter.
The Arsenic Content of Large-mouth Black Bass (*Micropterus salmoides* Lacepede) Fingerlings. Transactions, American Fisheries Society, vol. 61, pp. 150–160.
WRIGHT, STILLMAN.
Pollution in Western Lake Erie. The Fisherman, vol. 1, no. 6, pp. 3–4, 10, May 1932.
Plankton and The Fisheries. The Fisherman, vol. 1, no. 7, pp. 3–4, 11, June 1932.
Conditions of Life in Lakes. The Fisherman, vol. 1, no. 8, pp. 3–4, 12, July 1932.

The following progress reports covering the more important investigations of the Division during the calendar year 1932 were prepared in the main by the investigators in charge of the various projects.

NORTH AND MIDDLE ATLANTIC FISHERY INVESTIGATIONS

Investigations of fisheries of the Atlantic coast from Maine to Virginia continued in 1932 to be concentrated on scientific research needed to arrive at means of insuring the continued productivity of the fisheries based on the more important food fishes: Haddock, cod, flounder, mackerel, squeteague, scup, and butterfish. Decreased funds necessitated curtailment of activities in all phases of the work but more especially in the cod and flounder studies and the offshore work of the haddock and mackerel studies involving use of the fisheries research ship *Albatross II*, the latter being out of service after June 30 for lack of operating funds.

As in previous years, the staff, under the direction of O. E. Sette, was headquartered in Cambridge, Mass., where the biological laboratories and the Museum of Comparative Zoology of Harvard University have kindly provided laboratory and library facilities to the Bureau. This arrangement has had the advantage of not only providing for the physical needs of this group, but facilitated consultation with members of the various departments when special advice was needed for particular phases of the work. Especially profitable has been the ever available counsel of Dr. Henry B. Bigelow, professor of oceanography at Harvard University and Director of the Woods Hole Oceanographic Institution. The latter institution also provided valuable aid in detailing its research vessel *Atlantis* to two cruises in the interests of the mackerel investigations. The cooperation of Prof. A. E. Parr, curator of the Bingham Oceanographic Foundation at Yale University, in continuing his studies of the early life histories of fishes along the coast of New Jersey has provided results vital to the understanding of the natural economy of the commercial species of the Middle Atlantic region. The Montauk Yacht Club in providing dock facilities for live cars contributed to the success of a squeteague tagging project. The kindness of fishermen in providing the Bureau with records of their fishing operations; of fishing companies in putting their business records of fish receipts at the disposal of our staff; and of fishing captains in accomodating field observers aboard their vessels for the purpose of tagging fish and collecting biological data, have also greatly facilitated the work.

HADDOCK

The New England haddock fishery has, during the past few years, experienced decided changes in productivity, the total landings at the principal ports in this region having increased from about 70,000,000 pounds in 1921 to more than 240,000,000 pounds in 1929. From that peak the landings declined to about 137,000,000 pounds in 1932. These changes have been due to a multiplicity of causes the understanding of which is essential to any intelligent consideration of the fishery and its future. The attainment of this understanding is one of the primary objectives of the Bureau investigations begun in the fall of 1930.

The program of investigation briefly outlined in the annual report for 1930 has been continued during 1932 under the direction of William C. Herrington. Although the work was considerably curtailed owing to reduced funds, it was possible to continue the most fundamental observations during the past year.

Haddock population studies; biology and statistics.—Statistics from the fishing fleet have been collected by F. L. Widerstrom and A. A. Dallas throughout the year at the Boston Fish Pier and at sea. The Fish Pier collections included the records of the position and amount of fishing done for each trip landed, data on the size, age, and growth of the fish caught on each bank, etc. In addition, 20 field trips were made on commercial trawlers primarily to secure information on the abundance of the smaller size classes not landed. By using this material combined with the detailed information from the fleet operating records furnished by several of the major fishing companies, there has been assembled a practically complete record for all the offshore fishing activities of the New England ground-fish fleet.

The analysis of material on the relative abundance and distribution of the haddock population, handled principally by J. R. Webster, has shown that from many aspects the year 1932 has been the most interesting in the recent history of the New England haddock fishery. Following a continuous decrease since 1927 in the stock of haddock of commercial size (total abundance of haddock was greatest in 1927 although the greatest landings were in 1929 due to increased fishing effort), the winter of 1931–32 and summer of 1932 finally witnessed an increase in the abundance of marketable fish. Observations on the statistical and biological mechanics of this increase have provided some of the most important of our results for the past year both in respect to increasing our understanding of fluctuations of the fishery in the past and in more definitely determining a basis for our future expectations.

The bulk of the New England haddock landings during the past few years have come from Georges Bank (including South Channel and Nantucket Shoals). In 1932 this area accounted for about three quarters of the total New England catch. The principal efforts of the present investigation have consequently been concentrated in this region.

The annual report for 1931 considered the relatively poor condition of the fishery on Georges Bank during that year due primarily to intensive fishing combined with the failure of the reproductive cycle to produce any considerable number of young haddock over a period of several years (probably 4 or 5). Field observations during the fall of 1930 and during 1931 had shown that a group of young fish had finally appeared in considerable numbers and had reached a sufficient size in the fall of 1931 so that the larger ones were of commercial value. During the fall and early winter of 1931 the catch of large haddock continued to decline but the catch of scrod increased about 19 times over the same period of the previous year. At that time, however, we had few data to indicate how much this group of young fish would influence the catch during the next few years.

In 1932 the extensive population of young fish on Georges Bank increased in average size through growth from about 41 to 42 centimeters (1.5 pounds) to 47 to 48 centimeters (2.2 to 2.5 pounds). As a result during the summer of 1932 practically the entire group had reached scrod size and toward the latter part of the year a considerable part of them were sufficiently large to be sold as market haddock. Consequently, the catch per unit of fishing time, during the summer of 1932, experienced a sharp increase to the highest level since 1929 and averaged for the entire year about 35 to 40 percent better than during 1931 (though not approaching the record year of 1927).

The course of the fishery on Georges Bank during 1933 will depend on the effect of the abundant group of young haddock which have come into the commercial fishery during 1932. Length-frequency measurements indicate that very nearly all of this year class were of scrod size by the spring and summer of 1932. Since that time, no new group of young haddock has appeared which will affect the commercial fishery on Georges before the winter or late fall of 1933. Consequently, the only conclusion to be reached is that unless new conditions develop which differ markedly from those experienced during the past 2 years, the catch per day, all sizes considered, will not be appreciably better in 1933 than in 1932, and probably it will

be considerably less due to the mortality suffered by the population since 1932. Growth in average weight of the fish will partly compensate for the mortality but probably not sufficiently to maintain the catch at the 1932 level.

Data collected on trawlers at sea have shown that the 1930 spawning on Georges Bank was practically a failure; therefore, the next recruitment to the commercial fishery cannot take place until the 1931 year class reaches commercial size. This should be in the fall and winter of 1933–34. Haddock of this class are now taken, sometimes in considerable numbers, on southeastern Georges and some on the Northern Edge, but they do not appear to be as abundant as was the 1929 class at the same age. It will not be possible, however, to obtain any adequate measure of their importance until they become large enough to be brought into market with the commercial catch. No adequate measure of the abundance of the fish smaller than market size is possible until a vessel is available for periodic surveys of the young-fish population.

On the banks east of the Fundian Channel such as Browns, LaHave and Western, the picture is considerably different. The scrod catch from this area during the past year has been very low, but haddock too small to be marketed have at times been taken in great numbers. These small fish were just beginning to be brought in with the commercial catch in November and December 1932, as was shown by length-frequency measurements, and by a slight increase in scrod landings for this area. Their continued growth should bring all of them into scrod size during 1933 and 1934, which will help to counterbalance the scarcity of scrod to be expected on Georges Bank in the summer and fall of 1933.

Early life history.—The observations made on early life history in 1932 were limited to one trip on the *Albatross II*, covering the area from west of Nantucket Shoals to Browns Bank. Salinity and temperature records were taken at 51 stations and hauls for eggs and larvae made with 1- and 2-meter ring trawls at each station. Seven hundred drift bottles were also released at the different stations. The analysis of this material is providing extensive information on the distribution and drift of the haddock eggs and larvae, which is essential to any understanding of the extent to which one fishing bank is dependent on another for its supply of young. It may also help to determine the causes of the great variations in the success of different spawning seasons. This work will have to be discontinued in 1933 as the *Albatross II* will not be available.

The analysis of temperature, salinity, and drift bottle records has provided a consistent general picture of the system of currents on Georges Bank for the spring and early summer of 1931 and 1932. The results are substantiated by measurements of currents furnished us by the Coast and Geodetic Survey for 1- to 8-day periods at various points on Georges Bank during 1930 and 1931. Conditions in the spring of 1932, although in general similar to 1931, differed in certain details. It will be of interest to learn whether this change in conditions may have affected the abundance of the year class resulting from the corresponding year's spawning. The evidence on this score will not be available until late in 1933, when the haddock of the 1932 class should reach a sufficient size to be captured by the commercial nets.

No Bureau personnel was available in 1932 for the study of the collections of eggs and larvae. Fortunately, however, we were able to arrange with L. A. Walford for the analysis of the data in conjunction with his research work at Harvard University. The results so far have confirmed the conclusions from our hydrographic studies and help to provide an explanation why the small haddock of the 1931 class have so far been found in abundance only on eastern and southeastern Georges. Haddock of the 1929 class also were first found there in large numbers, apparently spreading as they grew older to the Northern Edge and to the South Channel. The evidence also indicates that there is little or no drift of eggs or larvae across the Fundian Channel either from Georges to Browns Bank or the reverse.

Savings gear.—During January and March 1932, three trips were made on the *Kingfisher* of the Portland Trawling Co. fleet and one on the *Exeter* of the Whitman, Ward, and Lee fleet to obtain data on the action of "savings cod-ends" used commercially on standard nets. The work was under the direction of Messrs. Herrington and D. Merriman, assisted by Messrs. Widerstrom, Dallas, and E. M. Leupold. The gear was satisfactory. It proved as durable as the standard type; fished as effectively; and released a large proportion of the small haddock. The amount of small fish taken, in comparison with a standard cod-end, depended on the average size of the small fish present on the banks. In the case of small haddock 20 to 35 centimeters in length, there was an escapement of 90 and 75 percent; between 35 centimeters and the commercial size of 40 centimeters the escapement was progressively less with practically no loss of haddock above the minimum commercial size.

The results of the work were described briefly in the April issue of Fishing Gazette and recommendations for the "savings gear" were published in the same journal in September. These recommendations consist primarily of an increase in the size of mesh in the net to give a minimum stretched mesh of 4½ inches clear, measured inside of the knots, or 5 to 5¼ inches measured between knot centers, depending on the weight of twine used. Other modifications in the construction of the net were recommended to give it increased strength and to assist in keeping the cod-end meshes open when the net is in operation. Certain other types of construction were found to give somewhat better selective characteristics but were not recommended as it has been considered that simplicity of the gear would facilitate its adoption by the industry.

MACKEREL

Among the leading fisheries of the Atlantic coast, that for mackerel is notable for its extreme fluctuation in yield. For the purpose of ascertaining the causes of such fluctuations and exploring the possibilities of alleviating the periods of scarcity, or of taking full advantage of the years of abundance, investigation of this fishery was begun by O. E. Sette in 1925 and has been continued through the succeeding years. The nature of the fluctuations was such as to indicate that the causes might lie in the variability from year to year in the numbers of young mackerel resulting from spawning. Hence the work was designed to determine the relative success of each spawning season, by observing the proportion of fish of each age in

the catch. This involved sampling the catch throughout the season and estimating the numbers of fish of each year of age in the catch. Since changes in size of the fleet might also be reflected in the annual catch, statistics of the catch of individual vessels have also been compiled since 1925.

In 1932 most of the sampling was done by F. E. Firth at New York during May and June; at Boston from July to October; and at Gloucester in November and December. Additional data were secured at various minor ports from Maine to New Jersey. During the year the mackerel fleet landed 3,802 fares aggregating 46,770,740 pounds. Of these, 2,020 fares representing 29,490,409 pounds were recorded by locality of capture through interviews with captains; 31,352 mackerel were measured from 1,168 fares; and scales were taken from 1,954 mackerel.

The age composition of the mackerel population, as derived from these data in 1932 and the previous 6 years, confirms the original supposition that variability from year to year in production or survival of young mackerel is the cause of the major fluctuations in the catch. In every instance during the 7-year period an increase in catch has followed a production of a large year class one or two seasons previous, and each decline was preceded by a season or two in which subnormal numbers of mackerel were produced.

Knowing the mechanics of these fluctuations, it remains to devise means of combatting their ill effects. At least three possibilities are apparent: (1) Adjustment to the fluctuations through prediction of future abundance, (2) lessening of the fluctuations by adjusting the fishing intensity so that successful year classes will be spread over enough years to bridge over the periods of subnormal production of young fish, and (3) control of the production of young fish.

Realizing the potential value of predictions the Bureau has been accumulating experience along this line during the past 5 years. From an appraisal of the rate of decline of each year class and the likelihood of augmentation by the advent of successful classes, the prospects for each season were estimated in terms of probable catch, and the results made public in fishing trade journals during the first 3 years, and by means of Bureau fishery circulars in the last 2 years. Of the 5 trial forecasts, 1 was noncommittal, 2 were approximately correct, 1 (1930) was too high by 17,000,000 pounds or 28 percent, and 1 (1932) was too low by 11,000,000 pounds or 42 percent. These two instances of disparity between prediction and catch were caused solely by unexpected changes in abundance of mackerel that were 2 years old. In all the years of record the predictions of abundance of mackerel older than this were reasonably fulfilled.

The difficulties of predicting the abundance of 2-year-old mackerel apparently have been brought about by the existence of at least two distinct types of year classes, distinguishable by changes in availability during the first 3 years of existence and by peculiarities of distribution. If this is the case, an accurate prediction would depend on the determination of the type in the yearling stage. From considerations too involved to enter upon in this report, it is believed that morphological studies of each year class, coupled with extensive marking experiments of each year class in the yearling stage, might enable such distinction to be made. Thus, it appears that an improvement in the prediction of 2-year-olds is contingent on provision being made for these two additional phases of st udy.

While improving the accuracy of predictions of the abundance of 2-year olds would rectify the most serious fault of the present forecasting system, there still would remain the question of how to predict the abundance of yearlings. Prior to their appearance in the fishery as yearlings, mackerel are too small to be the object of a commercial fishery; hence this means of appraising their abundance is lacking, and this category has been omitted from the predictions. Since yearlings often provide a large portion of the commercial yield, it would be useful to have them included. The most promising means of arriving at an estimate of their abundance is by annually estimating the numbers of mackerel surviving to the late larval stage. This involves special technique and must be pursued through a number of years to ascertain the relation between abundance of late larvae and the abundance of yearlings a year later.

To provide data on this subject, the Bureau's research ship *Albatross II* has been detailed to surveys of the spawning grounds during such portions of the last five spawning seasons as she could be spared from other duties. The early years were exploratory, to ascertain the time and place of spawning, and to design gear and devise methods that would give reliable measures of the relative abundance of larvae. It was not until the season of 1932 that equipment and methods were developed that could be expected to provide reasonably reliable results. The report on this season's operations may be considered as an outline of the minimum requirements.

From May until July the *Albatross II* was cruising almost continuously, visiting each of some 30 stations at about weekly intervals. As spawning begins first in the more southerly regions and gradually progresses northward, the area of survey was shifted correspondingly. During May the work was mainly at stations in the offing of Virginia, New Jersey, and New York. By June it was extended to southern New England waters. At each station hauls about one-quarter mile in length were made diagonally from below the 30-meter level to the surface. In the early season when larvae were small a 1-meter net with 0.6-millimeter mesh was used; later, when the larvae exceeded 8 millimeters in length, a 2-meter net with 1- to 2-millimeter mesh was also used. Although the *Albatross II* was taken out of service during the latter part of June, because of the lack of operating funds, the season's observations were extended into the latter part of July with the *Atlantis* which was kindly assigned to this work by the Woods Hole Oceanographic Institution. Altogether 239 stations were occupied, at which 372 hauls were made. The larval mackerel from all hauls have been counted and measured, but personnel has not been available for the clerical labor involved in computing the relative abundance at each stage, so that results cannot yet be reported.

A continuation of such surveys during successive years might enable forecasts of abundance of yearlings to be made, but with the withdrawal of the *Albatross II* from active service, this feature of the work must be held in abeyance and the mackerel predictions must continue to contain this element of uncertainty.

The matter of preventing extremes of fluctuations by relieving intensity of fishing effort on the successful classes so that they may continue abundant enough to bridge the gap caused by a series of reproductive failures, is further from attainment than predictions,

but if feasible, should eventually be of far greater effect in stabilizing the fishery. A continuation of the present program of analyzing the catch may provide part of the knowledge necessary for such control but it should be accompanied by tagging experiments to discover how much of the decreased availability between yearling and 2-year-old mackerel of some year classes is caused by fishing strain, and how much to natural morta ity and changes in habits with increasing age. For instance, the 1928 class yielded 29,000,000 yearling fish, but only 10,000,000 fish during the following year when they were 2 years old. Was this because too many yearlings were caught? If so, would protection to yearlings have prevented the decline in catch in the following year? A properly designed marking experiment carried on regularly through enough seasons to establish the usual course of events might indicate the value of such protection. Inasmuch as such a marking program would also be useful in improving predictions, it is important that means be provided for this as soon as possible.

That fluctuations might be smoothed out eventually by controlling young fish production is a remote possibility, its likelihood of attainment cannot be appraised until more is known about the causes of failures. Current scientific opinion is that the phenomenon of poor year classes among marine fishes is due to excessive mortality in the larval stage, but there are no definite data on the subject. The surveys of the *Albatross II* on the mackerel spawning grounds have been designed to throw light on this question as well as to be of aid in predictions as previously mentioned. With the tying up of this ship for want of operating funds, progress has been halted. As an adjunct to the work at sea, laboratory experiments were carried on during the year by Leonard G. Worley to determine the percentage of mackerel eggs that hatch at different temperatures, while rearing of fish larvae under laboratory conditions was undertaken by Louella E. Cable to learn their food requirements.

COD

Studies of the migratory habits of the cod were continued during 1932 by William C. Schroeder, but on a reduced scale owing to reduction in funds available for the purpose.

The principal item in the year's program was the release of 1,489 marked cod along the coast of Maine to learn whether any of the abundant stock of 2- and 3-year-old cod that inhabit the inshore waters of New England move offshore as they grow to larger sizes, thus contributing to the commercially important stocks of large cod on the offshore banks. For this purpose it is necessary that the tags remain with the fish for a number of years. Since the percentage of external tags lost from the fish is sometimes large, the "belly tag", a celluloid strip inserted into the body cavity according to the method developed by R. A. Nesbit, was used in this experiment. Fears that this type of tag might not be detected as regularly as external tags proved groundless, for the 10.7 percent returned during the first 6 months after release about equals the percentage of returns from comparable experiments with external tags.

To provide additional evidence as to the merits of various methods of tagging, last year's spawning stock of cod from the hatchery at Woods Hole was used to determine the comparative durability of

celluloid disk tags attached at different positions on the fish. Unfortunately, only 304 cod were available; 151 were tagged on the caudal peduncle, 153 on the opercle. During the 11 months since release, 5.3 percent of the caudal tags and 8.5 percent of the opercle tags have been returned. While this seems to favor the position on the opercle, the numbers are too few to be decisive.

Returns from previous years' taggings, that came in during 1932, confirm the previous conclusions that the summer stock of Nantucket Shoals migrates to New York and to New Jersey waters for the winter, returning in the spring to spend the summer on the Shoals. There was also a slight scattering from the Shoals toward the north and east, mainly of larger sizes. The cod off the coast of Maine continued to provide local returns chiefly, only a few coming in from distant points and these mostly from the eastward. The newly marked fish with the more permanent tags, however, may modify this when the 2- and 3-year-old fish bearing them grow to larger sizes.

Mr. Schroeder's resignation, in June 1932, to join the staff of the Woods Hole Oceanographic Institution in capacity of business manager, is a serious loss to the cod-investigating program. It is somewhat offset by his kindness in personally undertaking to continue the analysis of returns from experiments under way and to do such further work as may be possible in his new position.

FLOUNDERS

Although shortage of funds prevented further work on the winter flounder (*Pseudopleuronectes americanus*) the tagging experiment of February to April 1931 continued to produce returns during 1932. Of the 4,179 flounders tagged, 141 were returned during 1931 and 64 during 1932. These indicate that the winter spawning population of Waquoit Bay migrates through the sounds in the spring and summer, some going eastward to the Chatham and Nantucket Shoals region and some westward to the Long Island region. In a few instances, surprisingly extensive migrations were indicated: One to the eastward as far as Georges Bank and one to the westward as far as Tuckerton Bay, N.J. Somewhat greater trend toward the west was shown in 1932 than in 1931. In the winter many flounders returned to Waquoit Bay where they were originally tagged.

SHORE FISHES OF THE MIDDLE ATLANTIC STATES

Investigation of the causes of fluctuation in yield of shore fishes off the Middle Atlantic States, begun in 1927, was continued under the direction of R. A. Nesbit, with data being obtained at Woods Hole, Mass.; Montauk, N.Y.; and Wildwood, N.J. Because of reduced appropriations the bases maintained in 1931 at Fire Island, N.Y.; Belford, Long Branch, Deal, Seaside Park, and Beach Haven, N.J., were abandoned in 1932. Observation of the winter-trawl fishery for Middle Atlantic shore species was carried out at Portsmouth, Va.

Squeteague.—This is the most important of the shore fishes of this region. The average annual catch along the Atlantic coast is more than 30,000,000 pounds with a value of more than $1,000,000. Of this total nearly one half is ordinarily taken in the Middle Atlantic States. In addition to its commercial importance, the squeteague is

highly prized by sportsmen and contributes largely to the recreational value of the shore line of these States.

Fluctuations in yield appear to be caused by variations in the numbers of young fish added to the stock each year, for two cases of increased abundance caused by unusually large increments of 2-year-old squeteague have been noted during the course of the investigation. In 1928 the stock of squeteague in southern New Jersey was augmented by the appearance of large numbers of fish of the 1926 brood. In 1929, 1930, and 1931 these fish returned to the same locality in considerable numbers, accounting for a larger proportion of the catch than any other year class during these years. By 1932 the numbers of fish of this brood had greatly decreased, and since no other brood of comparable magnitude entered the fishery meanwhile, the yield for that year declined. Similarly, in 1929, a large brood of 2-year-old squeteague appeared near Montauk, N.Y., with a corresponding increase in the catch. This brood dominated the fishery in 1929, 1930, and 1931, but by 1932 few returned, and the catch reverted to levels as low as in 1928.

In addition to these two conspicuously large broods, appearing first as 2-year-olds, minor contingents of yearling fish have appeared in southern New Jersey in all the years covered by the investigation, and near Montauk, N.Y., in 1932. These fish are remarkable in that while still yearlings they are always approximately as large as the 2-year-old fish of the dominant year classes described above. Moreover, growth increments of these fish in their first season, as calculated from the scales, are greater than the corresponding increments for the dominant 2-year-olds.

Thus there appear to be two distinct types of young fish entering the fishery in variable numbers from year to year. The first type consists of slow-growing 2-year-olds which occasionally appear in large numbers. The second consists of fast-growing yearlings which have not appeared in sufficiently large numbers during the course of the investigation to affect the yield greatly.

The rate of growth of the 2-year-olds as calculated from the scales agrees closely with the observed rate of growth of young fish during their first two seasons in Virginia and North Carolina. Moreover, slow-growing yearlings are abundant in these States, in marked contrast to their virtually complete absence north of Delaware Bay. Thus, there is much to suggest that the most important increments to the New Jersey and New York stocks of squeteague during the period 1928–32 consisted of fish which had spent their first two growing seasons south of Delaware Bay.

This hypothesis is supported by the results obtained by Prof. A. E. Parr, curator of the Bingham Oceanographic Foundation, who continued his studies of spawning and nursery areas of southern and central New Jersey and at Woods Hole, Mass. As in the preceding years, squeteague eggs were taken in abundance, but larvae were not found in New Jersey waters. This persistent absence of squeteague larvae, in marked contrast to their abundance in lower Chesapeake Bay, suggests the possibility that the eggs fail to hatch in the waters of New Jersey. It has been noted that the eggs are produced in the two localities simultaneously but at a time when water is colder in Delaware Bay than in Chesapeake Bay. It is planned to carry out

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experiments to determine whether squeteague eggs are capable of hatching at the temperatures usually prevailing in Delaware Bay during the spawning season.

It has proved difficult to test the view that northern stocks of squeteague are largely recruited by migration of 2-year-olds from the South, by tagging squeteague in southern waters. The species is so soft-fleshed and so weak-boned that external tags are not retained in adequate numbers for longer than a few weeks. In 1930 Mr. Nesbit devised a new method of tagging which was first used successfully with squeteague in 1931. This consists of inserting a strip of colored celluloid into the body cavity of the fish through a small incision in the body wall. Each strip bears a notice of reward, a return address, and an identifying number.

Of approximately 900 slow-growing yearling squeteague tagged in this manner by W. C. Schroeder in Chesapeake Bay in 1931, 18 were recaptured in 1932. None was retaken north of Delaware Bay. However, since the New Jersey and New York catches in 1932 included very few slow-growing, 2-year-old fish, the hypothesis cannot yet be regarded as disproved, for the origin of these sporadic incursions can be determined only in the years in which they occur. In a further attempt to test this hypothesis, approximately 1,900 squeteague were tagged in the same manner in October 1932 in Pamlico Sound, N.C.

In order to determine whether the minor increments of yearlings to the New Jersey and New York stocks are derived from the juveniles observed each autumn in northern New Jersey and New York, approximately 1,900 juveniles were tagged in October 1932 near Montauk, N.Y.

Should the results of tagging experiments eventually justify the view that many or most of the squeteague taken in New York and New Jersey are immigrants from the South, it will be desirable to estimate the relative contributions of the southern and of the local nursery areas. The differences in rate of growth are sufficient to make this possible if the growth increments of the earlier years can be calculated accurately from the position of the year rings in the scales. Such calculations can be made only if the relation of scale growth to the growth of the body be understood thoroughly. Earlier observations of this relation were checked by a number of experiments at the Woods Hole laboratory of the Bureau, and at the laboratory of the Woods Hole Oceanographic Institution, and were found to be correct. Thus, there has been established a sound basis for separating the two types of increment to the squeteague stocks of the region, not only in the year in which they first appear but in subsequent years as well.

Scup.—In the annual report for 1931, it was shown that although the yield of scup in the summer pound-net fishery has been subject to wide fluctuations, this species has demonstrated its ability to recover naturally from low levels of abundance. The pound-net catch of New Jersey rose by the influx of successful broods from one of the lowest on record in 1928 (316,000 pounds) to a new high level of 4,100,000 pounds in 1931. According to preliminary statistics, the yield of 1932 was only moderately less than the record catch of 1931. These higher yields represent actual increases in abundance, for there was no corresponding increase in intensity of fishing.

Prior to 1929 the scup was generally considered a "summer fish" and constituted an important product of the summer pound-net, trap, and seine fisheries along the Atlantic inshore waters from the Chesapeake Bay to Cape Cod. However, with the rapid growth of a winter-trawl fishery [2] off the Virginia Capes since the winter of 1929, an additional strain has been placed on the species, and the question has been raised whether or not it can withstand the year-round exploitation to which it is now subject. Compilation and analysis of the data bearing on this question were carried out by W. C. Neville.

It was first necessary to determine whether the winter trawlers and the summer pound-net, seine, and trawl fisheries were drawing on the same stock of scup. Marking experiments have disclosed a migration of scup in the fall from the summer fishing ground to the winter fishing ground, and a spring migration from the winter grounds off Virginia to the summer area along New Jersey. Comparison of the size and age composition of the catches of the summer and winter fisheries disclosed that broods of scup that have contributed largely to either the New Jersey, inshore, summer, pound-net fishery or to the more offshore summer-trawl and seine fisheries have also been prominent in the catches made by the trawl fishery in the following winters. Thus, both fisheries appear to be drawing on the same population.

In order to determine whether the double strain on the stock was affecting the yield in one or the other, or both of the fisheries, an analysis was made of the changes in their yields. As indicated in the first part of this report, the summer fishery gives no indication of a decline in abundance to date, and this in spite of the fact that the winter-trawl fishery of 1931–32 drew upon the same age groups.

The total quantity of scup landed at Virginia ports by the winter trawlers increased from approximately 1,600,000 pounds in 1930–31 to approximately 2,200,000 pounds in 1931–32. This increase, however, was caused entirely by increased fishing effort. Actually, there was a decrease in availability, for the catch per trip declined from 7,900 pounds in 1930–31 to 2,800 pounds in 1931–32. It might appear that this decline in the catch per trip, and the shift to smaller sizes in the composition of the catch of the winter-trawl fishery, was perhaps the first indication of depletion from overfishing; but this is not necessarily true for other factors were responsible for these changes. These are: (1) In the winter of 1931–32, scup were probably much less readily available as a result of the schools scattering widely over a larger expanse of coastal sea bottom; this because the bottom water remained warm over a much larger area of the coastal plain in that winter than in the preceding winter.[3] (2) The change in the hydrography of the region resulted in the greater availability of other important food fishes, especially of sea bass, and probably caused a diversion of fishing effort from scup to the more readily caught sea bass. These conditions appear adequate to explain the decline in the catch of scup per trip at sea in 1931–32.

If the number of returns of tagged fish is indicative of fishing intensity, there is little evidence that the scup fishery is being sub-

[2] An account of this fishery is given in Winter-trawl Fishery off the Virginia and North Carolina Coasts, by John C. Pearson. Investigational Report No. 10, Bureau of Fisheries, 1932.

[3] For a description of the changes in the hydrographic conditions between the winters of 1930–31 and 1931–32, see Temperature and the Southern Trawler by William C. Neville, Fishing, January 1933.

jected to any great strain. To date there have been only about 1 percent returns from a total of 5,228 tagged scup. This low percentage cannot be attributed wholly to the loss of tags by becoming detached or to the death of the fish as a result of the marking operation, since returns were well distributed over a period of almost a year. Moreover, in laboratory tests it has been found that tagging causes very little mortality, and that virtually all scup retain the external celluloid disk tags for a period of 4 months, and the majority for at least 1 year. But in order to eliminate any uncertainty due to a possible loss of tags, we may confine our consideration to the returns for the first 4 months after tagging. During such periods, less than 1 percent of the marked scup were returned. This is exceedingly low in comparison with returns of 4 to 20 percent obtained during comparable periods with squeteague, cod, and striped bass, and may be taken to indicate that the fishery at present is catching only a very small part of the general stock of scup in the sea.

It appears, therefore, that although now subject to year-round exploitation, the scup fishery has not to date shown any indication of an appreciable decline in abundance directly attributable to the additional strain. Consequently, there appears to be no present need for restriction of the fishery.

It is important, however, that observation be continued, for this conclusion is based on present conditions of abundance and fishing intensity; and experience has shown that both are subject to rapid change. Each year since 1929 has seen a greater number of trawlers engaged in the winter and summer fisheries, and there is no indication that this increased strain has reached its maximum. The history of the fishery suggests that the yield must eventually decline from present levels, and when this occurs the Bureau should be in a position to judge whether the decline is natural or whether it is due to overfishing, and to make new recommendations to fit the new conditions. This can be done only if observations of abundance, age composition, fishery intensity, and hydrography are continued.

Butterfish.—Continuation of butterfish studies by H. M. Bearse in 1932 has confirmed the view that fluctuations in yield of this fishery are caused primarily by dominant year classes, and that no depletion by overfishing has taken place. Appearance of another large year class in 1932 indicates that a continuation of good yields is to be expected in the immediate future.

CHESAPEAKE BAY INVESTIGATIONS

The studies of the life history of the striped bass or rockfish (*Roccus lineatus*) begun by John C. Pearson in 1931 were continued until June 30, 1932, when curtailment of appropriations forced abandonment of this activity.

Of three hundred and four 2-year-old striped bass tagged during July and August 1931 off Annapolis, Md., a total of 81 fish or 26½ percent were retaken by anglers and commercial fishermen within the first year after release. Most of the recaptured fish were secured north of Annapolis, in the upper bay and tributaries, during the fall and winter following release. In the spring of 1932, however, several recoveries as far south as the upper Potomac and Wicomico Rivers indicated a dispersion of striped bass throughout the upper half of

the bay from the deeper channels which form the wintering grounds of the species. No recoveries have been reported since the spring season.

Observations in upper Chesapeake Bay showed that the striped bass spawn in the Susquehanna River, above Havre de Grace, during the latter part of May. The large and rather delicate eggs of the species were taken in abundance by townets in the Susquehanna and supplied the first evidence on record concerning a natural spawning area of the striped bass.

EXPERIMENTAL REARING OF MARINE FISH LARVAE

The cause of fluctuation in commercial fisheries has been traced to a corresponding fluctuation in the survival of the young of the various species. To determine the physical and chemical factors effecting their survival, Louella E. Cable continued experiments on rearing marine fish larvae at the Woods Hole station during the summer of 1932.

It was shown that the most critical period of development comes a few days after hatching, when the yolk sac is nearly or wholly absorbed and the young fish are ready to take food. Very few larvae feed in the laboratory in standing water, and those that do seldom survive the critical period. Apparently stimulus is needed to make them sufficiently alert to catch food and keep them active after feeding and to create the need and desire for more food for after feeding they sink to the bottom making little effort to swim about. The current rotor devised by Dr. P. S. Galtsoff and Miss Cable while allowing for a constant change of water without danger of loss or injury to the larvae, provides a gentle current which buoys up the larvae, stimulates them to action, and keeps the food suspended. Such gentle currents were found to be a definite aid to the fish larvae in catching their food.

The larvae of those species studied, mackerel, sand dab, Prionotus, *Paralichthys oblongus*, tautog, cunner, and Urophycis, respond in like manner to similar conditions. All develop more rapidly at high than at low temperatures; all are injured by contact with rough surfaces and are very sensitive to water pollution, and all die within a few hours after absorption of the yolk sac unless they begin to feed at that time. In the labaratory the early post larvae of these species will feed on copepods and make rapid growth. Under sanitary conditions mortality before the critical period is almost negligible, being less than 10 percent in many cases.

Mackerel larvae, at least, are able to adapt themselves to salinities varying from 26 to 32 per mille. The limits of adaptability may be found to be even more widely separated.

SOUTH ATLANTIC AND GULF FISHERY INVESTIGATIONS

INVESTIGATIONS OF THE SPAWNING HABITS, EMBRYOLOGY, LARVAL DEVELOPMENT, AND RATE OF GROWTH OF FISHES

Studies pertaining to the spawning habits, the embryology, larval development, and rate of growth of fishes of the South Atlantic States were continued by Dr. Samuel F. Hildebrand, assisted during most of the year by Louella E. Cable and the rest of the year by Nell Henry. Besides the collection of additional material and data, and preliminary

studies and identifications, a manuscript amply illustrated with drawings, on the spawning habits, the embryology and larval development of three species of blenny was completed and submitted for publication. Another manuscript, with drawings, embodying the results of similar studies pertaining to four species of goby also was completed and submitted for publication. Although the blennies and gobies studied are too small to be of direct economic value, they are numerous enough in many localities to serve as a forage fish for larger commercial species.

Comprehensive studies of the larval development, the distribution of the young, and rate of growth of eight species of Sciaenoids, namely, *Menticirrhus americanus*, *M. saxatilis*, *M. littoralis*, *Larimus fasciatus*, *Stellifer lanceolatus*, *Cynoscion regalis*, *C. nebulosus*, and *C. nothus* were completed. A manuscript, well illustrated with drawings, embodying the results of the studies of the 5 species named first was prepared, and an account of the 3 species of Cynoscion was well under way at the close of the year.

The 3 species of Menticirrhus, or king whiting, as well as the 2 species of Cynoscion (*regalis* and *nebulosus*) or sea trout studied, are all of much commercial importance. The extensive additions to our knowledge of the life histories of these fishes will prove most valuable when the time comes, as it no doubt will, that regulations for their protection and conservation must be enacted.

ICHTHYOLOGICAL STUDIES

Ichthyological studies of the marine fishes on the coast of the Southern States were continued. Particular attention was paid to the summer flounder and allied species of the genus Paralichthys. These species which are all food fishes of much importance in the fisheries are very similar in appearance and difficult to distinguish. This was an almost insurmountable stumbling block in the way of a study of their rate of growth, habits, and life history. By an intensive study, distinguishing characters have been recognized by which the different species may be positively segregated without difficulty. The geographical distribution of the various species has been worked out, and also, their economic importance.

On the coast of the Southern States there are present two common and distinct species of flounders belonging to the genus Paralichthys. The interesting fact was also discovered that one of these species is naturally quite small, and not of much important commercial importance except for local consumption, but few reaching a sufficient size to enter the channels of trade; while the other species is the common market fish. In other words, individuals of the smaller species are not the young of the larger commercial species, as was generally believed. This fact, of course, has an important bearing on the problem of conservation.

Needed systematic studies of the common fishes of the Gulf coast belonging to other groups as well were continued.

SHRIMP INVESTIGATIONS

The investigation of the shrimp, which ranks first on the list of the important fisheries in the South Atlantic and Gulf area, has been continued during 1932, under the direction of Dr. F. W. Weymouth, professor of physiology at Stanford University, California, and Mil-

ton J. Lindner. This investigation, started in 1931, covers practically the entire range of the commercial fishery and has been supported by the States of Louisiana, Texas, and Georgia. Headquarters are maintained in New Orleans, the center of the shrimp industry, in quarters kindly furnished by the Louisiana Department of Conservation, and field stations are located at Beaufort, N.C., Brunswick, Ga., and Aransas Pass, Tex. Intensive life history and oceanographic studies are being carried on in Louisiana, with the excellent cooperation of the Louisiana Department of Conservation, through its bureau of research and statistics. This department, besides supplying quarters for the Bureau's investigators, also furnishes the crew and operating expenses of Fisheries launch *Black Mallard.* Through the generous support of the Texas Game, Fish, and Oyster Commission and the Georgia Department of Game and Fish, the Bureau of Fisheries was enabled to place an observer at Aransas Pass, Tex., to sample the commercial shrimp catch, and another at Brunswick, Ga., with Fisheries launch *No. 58* and crew, to study the habits of the shrimp in that area.

As stated in the last annual report, the Bureau's investigators confined themselves chiefly to the problems concerning (*a*) life histories of the principal commercial species, including spawning, embryology and larval history, post-larval growth, longevity, and migrations; (*b*) abundance analyses; (*c*) biometrical studies of the principal species in respect to racial determinations and migrations; and (*d*) effect of fishing in relation to gear, localities, and time on composition of the shrimp catch and on the other species of economic importance. The investigators of the Louisiana Department of Conservation were to direct their activities toward the solution of the problems in respect to (*a*) habits and reactions of the young and adult shrimp in relation to food and food getting, migration, molting, spawning, and the effects of temperature and salinity; (*b*) the anatomy of the principal species of shrimp in relation to spawning and feeding; and (*c*) diseases and parasites affecting the shrimp.

In an attempt to attain these objectives, during 1932, in the region near Beaufort, N. C., 13 beam trawl and 76 otter trawl hauls were made for shrimp in both the inside and outside waters; 14 seine hauls were made for smaller post-larval shrimp in the muddy creeks and a number of plankton tows were taken in the waters adjacent to Beaufort, for the larval stages. Along the entire Georgia coast, launch *No. 58* made 362 hauls for shrimp with a regular 50-foot commercial otter trawl. Besides the otter trawl collections, a number of plankton tows and seine hauls were made. At Aransas Pass, Tex., 262 trawl boat catches were sampled. In Louisiana 188 otter trawl hauls, 106 plankton tows, and 27 seine hauls were made. With each otter trawl haul an accompanying hydrographic station was made. From the above operations, during 1932, over 85,000 shrimp were measured, sexed, and the gonad development recorded.

The operations in Louisiana are centered around 3 stations in Barataria Bay and 3 stations in the Gulf adjacent to the bay with occasional investigative trips to stations in other parts of the State. Barataria Bay is the focus of one of the most productive shrimping grounds in Louisiana and was selected as the base for intensive study because of its commercial importance and accessibility to New Orleans

where the laboratories are located. The stations have been so chosen that they represent a wide variety of ecological conditions that grade from the brackish waters of Bayou St. Denis in upper Barataria Bay to the saline waters of the Gulf 12 miles off Barataria Pass.

The stations are visited twice every half month and at each an otter trawl haul is made, the surface- and bottom-water temperatures, salinity, pH and turbidity determined, and, if conditions are suitable, a plankton tow is taken. When the trawl haul is completed the catch is emptied on deck and separated into piles according to species. Each species of fish is counted and recorded and a random sample of 200 *Penaeus setiferus* (common shrimp) is taken. Each shrimp in the sample is sexed, measured, and the gonad development noted. The measurements are made from the tip of the rostrum or "spine" to the end of the telson or "tailfin." They are taken to the nearest millimeter on an especially devised measuring board and recorded as total length. As the shrimp of lesser economic importance are found in the random sample of 200 common shrimp, they are separated out and later the same procedure of sexing, measuring, and gonad examination is carried out on them. In this way the ratio of the common shrimp to other species in the catch is determined.

Somewhat similar sampling procedures are followed in both North Carolina and Georgia, but in Texas the method of sampling is altered to fit the commercial fishery. Here the observer is located at a cannery from which he obtains random samples of shrimp from eight commercial trawl boats each week. The length measurements and other observations on the specimens are made in the same manner as in Louisiana.

There are three species of sea shrimp, all of which are members of the family *Penaeidae*, that are of commercial importance in the South Atlantic and Gulf States. The common shrimp or lake shrimp (*Penaeus setiferus*) comprises over 95 percent of the total, while the grooved shrimp (*Penaeus brasiliensis*) and the sea bob (*Xiphopenaeus kroyeri*) together yield the remainder. Since the common shrimp (*Penaeus setiferus*) is by far the most important commercial species, the investigations have been centered chiefly on solving the life history of this species. These investigations have already yielded many facts concerning the life history of the common shrimp (*Penaeus setiferus*), and a report is now in press covering some of the findings—a brief summary of the more important ones will be given here.

From an analysis of the length-frequency data gathered in North Carolina, Georgia, Louisiana, and Texas, it is evident that the common shrimp remains in the catch for only 1 year. In the Georgia area, the shrimp spawn from about the latter part of March until about the end of August. The young shrimp hatched in the spring, grow rapidly and appear in the fishery during July, with a mode at about 90 millimeters. These small shrimp-of-the-year furnish the heavy fall and early winter catch. The following spring they mature, spawn, and pass from the fishery. By the first of October, there is none of these year-old shrimp remaining in the Georgia waters; they disappear rapidly during July, August, and September, following the appearance of the young of the succeeding year class.

From all indications, the spawning seems to be in the outside waters or at least in waters of high salinity. The young post-larval stages, from 8 or 9 to 100 millimeters, are found in abundance on the inside

in the bays, creeks, and lakes associated with high temperatures, low salinities, and shallow muddy-bottom waters. As these young individuals grow, they move to more saline waters.

There is a differential growth rate between the males and females with the latter outstripping the former. In the young under 100 millimeters there is no significant difference in size between the sexes. In the spring, however, during the development of sexual maturity a differential growth is evident, in which the males are outstripped, so that in the spawning population the females are longer by nearly a tenth. There are also other morphological differences between the sexes; the males are characterized by having the inner ramus of the first pair of swimmerettes elongated and modified to form a structure termed the petasma which is apparently used in the transference of the spermatophores. This structure is lacking in the female.

That temperature influences the shrimp is evidenced by the fact that in Barataria Bay, La., during the fall of 1931, there was found a high positive correlation between the weekly average length of the shrimp and the average weekly air temperature. At the same time, there was a high negative correlation between the proportion of females in the catch and the temperature. In other words, an increase in air temperature was associated with an increase in the average length of the shrimp and a decrease in the proportion of females. Similarly a decrease in temperature was associated with a decrease in the average length of the shrimp and an increase in the proportion of females.

During the spawning season, there is evident a wide divergence in the proportion of sexes in the inside and outside waters of Georgia. From September 1931 to March 1932 the females were slightly more abundant than the males in both the inside and outside waters. Beginning about April (for both 1931 and 1932) the percentage of females on the inside rose rapidly until by June over 80 percent of the population in the inside waters was composed of this sex. After the June peak, the percentage dropped until the disappearance of the large year-old shrimp from the catch made it impossible to follow the sex ratio of this group. During the period of rapid rise in the proportion of females on the inside, there was also a change in the proportion on the outside. At first there was a rise in the percentage of females then a rapid drop to about 30 percent, where it remained until the large group disappeared.

For the first two months following the appearance of the young shrimp-of-the-year in the commercial catch, the males outnumbered the females in this group in both the outside and inside waters. That the rapid rise of the proportion of females on the inside and the decline on the outside was closely associated with spawning can hardly be doubted, as these changes in the population appeared during the height of the spawning season.

The shrimp is apparently omnivorous in its feeding habits as a wide variety of both plant and animal remains have been found in the stomachs.

In an attempt to determine the effect of trawling on species other than shrimp, an extensive survey was carried on for 2 years in Georgia. From October 1, 1930, to September 30, 1932, 386 hauls were made by launch *No. 58* in the inside tidal waters of Georgia suitable for commercial trawling operations. (Similar studies are now in progress

in Louisiana.) In these 386 hauls made with the ordinary commercial gear, a total of 530,176 fish were taken, an average of 1,373½ fish per haul. The table given below shows the total number and the average number per haul of bullhead minnows, important sports fish and all other species caught in these 386 hauls.

Species	Total number of fish taken in 386 hauls in inside waters	Average number of fish per haul	Species	Total number of fish taken in 386 hauls in inside waters	Average number of fish per haul
Bullhead minnow	238, 354	617. 5	Bluefish	394	1. 0
Spot	49, 174	127. 4	Other species	158, 909	411. 7
Croaker	45, 809	118. 7			
Summer trout	25, 952	67. 2	Total	530, 176	1, 373. 5
Whiting	11, 584	30. 0			

As shown in the table, almost half the total catch (45 percent) was represented by the bullhead minnow (*Stellifer lanceolatus*), a fish of no sport or commercial value, but still of importance as a source of food for other species. Excluding the bullhead minnow, five sports fish, namely, croaker (*Micropogon undulatus*), spot (*Leiostomus xanthurus*), summer trout (*Cynoscion regalis*), whiting (*Menticirrhus americanus*), and bluefish (*Pomatomus saltatrix*), comprised 45½ percent of the fish remaining. Since the majority of summer trout, croakers, spots, and bluefish, and a large proportion of the whiting, were undersized and immature fish that could not be utilized for food purposes, it is evident that a great deal of destruction was done by the trawlers. In the ordinary commercial operations most of the fish and smaller shrimp caught in the trawls are dead or moribund before the process of sorting has been completed and they can again be returned to the water. If the young individuals are not dead, they are so weakened from packing in the trawl and exposure on the deck of the vessel that when thrown back they fall easy prey to sea gulls and larger fish. Furthermore, since the inside waters of Georgia are restricted in extent and since they are important nursery grounds for shrimp and many species of fishes, it has been recommended that these inside waters be closed to trawling.

Experiments are in progress in Louisiana which it is hoped will throw light on the amount of shrimp that escape through the meshes of the trawl and to determine if it is feasible to devise a trawl which will allow the smaller shrimp to escape unharmed. This is not an easy undertaking as the shrimp are readily killed and their shape makes it difficult for them to pass through the meshes of a net without becoming entangled and badly mutilated. A canvas tubing is being devised which will fit over the cod end of a trawl and allow everything that passes through the trawl to be washed into a live car on the surface. With this apparatus the effectiveness of a savings gear can be determined as it will enable a record to be made not only of the number of shrimp and small fish escaping through the meshes of the trawl, but also whether these individuals are living or dead—a necessary requisite of any savings trawl.

With the shrimp fishery based wholly on immature and maturing individuals and with the evident short life of the common shrimp,

it is apparent that when depletion once sets in it is likely to be disastrously rapid, and all possible methods should be used to foresee depletion and prevent its occurrence. In Louisiana, steps toward this end have already been taken. Commissioner of Conservation Robert S. Maestri, at the instigation of M. J. Lindner of the Bureau of Fisheries, and Col. Hu B. Myers and James P. Guillot of the Department of Conservation, inaugurated a system of shrimp-catch records which will eventually yield invaluable information on the abundance of the shrimp. It is required of all dealers and ice-boat captains, or anyone who buys shrimp directly from the fishermen, to fill out a form, in triplicate, giving the name of the dealer, the name of the fisherman, the name of the boat, the type and size of net used, the locality in which the shrimp were caught, the amount of shrimp, and the price paid. These forms are furnished free by the State to all dealers, and the field agents of the Department of Conservation collect the completed tickets twice each month. It is hoped that the other States in which shrimping is an industry will follow the excellent example set by Louisiana in securing information on the status of the fishery, for it is only from such records that sufficient information can be obtained to determine the real abundance of shrimp.

PACIFIC COAST AND ALASKA FISHERY INVESTIGATIONS

With the exception of the investigation of the sockeye salmon of Puget Sound the major field projects of the Pacific coast fisheries were continued in Alaska. No new programs of investigations were initiated during 1932, and because of curtailment of funds the work dealing with the steelhead trout of the Rogue River was discontinued. Funds were not available for the employment of an investigator to take charge of the Bristol Bay red-salmon problem. However, scale samples from this region have been secured through the cooperation of the Alaska Division of the Bureau of Fisheries.

All of the investigators have been stationed at the Fisheries Biological Station in Seattle when not in the field.

PUGET SOUND SOCKEYE-SALMON INVESTIGATION

An investigation dealing with the sockeye-salmon fishery of Puget Sound was initiated by J. A. Craig during the preceding year. The program adopted in relation to this particular problem had as its aim the devising of a reliable index of the annual abundance of the sockeye salmon and solving the question of whether or not the abundance of the fish varies in a regular and constant manner during each fishing season; also, if these regular variations do exist whether or not they are due to individual races of these salmon migrating through the fishery at fairly constant dates from year to year. If the presence of such individual "runs" or "races" can be established, their fluctuations in annual abundance can then be studied in detail apart from the total run, since it is possible for certain parts of a red-salmon migration to be more severely depleted than others.

In order to solve these problems, a statistical study was made of the daily catches of a selected group of traps. Records were procured from the years 1917 to 1930, inclusive. Since the traps selected had not been moved in location or altered in construction during these years, each constituted a constant unit of fishing gear. Records of

daily catches were available, hence a fishing day provided a constant unit of time. From these data the result or catch of a constant unit of fishing effort was calculated from the records of each trap, and from the records of all of the traps for each year or portion of a fishing season. Seasonal trends of the catches were also computed for the individual years.

Using standard methods for computing index numbers, the records of the individual traps were combined into an index of size of catch per unit of fishing effort for all of the traps during the years in which data were available. Since these catches are the results of the use of constant units of fishing gear it should be a reliable index of the abundance of the Puget Sound sockeye salmon. The total amount of fishing gear on Puget Sound has decreased during the years under consideration. Therefore, any drop in average catch per unit of effort is not due to increased competition between gear. The trend of this index indicates a steady decline in the numbers of sockeye salmon from 1917 to 1930.

An outstanding feature of the seasonal trend of the fishery is a large peak in midsummer. This period of great abundance has apparently suffered the greatest depletion.

From the results thus far achieved it appears that it may be possible to correlate certain regular seasonal fluctuations in abundance with definite races of salmon entering the Fraser River.

Catch records from the fishing seasons of 1931 and 1932 have only recently become available and will be added to the data so far considered to complete this study.

During 1929 an experiment was undertaken at the Bureau of Fisheries' hatchery at Birdsview, Wash., to determine the most effective time at which to liberate young sockeye salmon. With this object in view 24,000 fingerlings were liberated in the fall of 1929 after being marked by the removal of their left ventral fins. On the following spring another 24,000 fingerlings from the same brood were liberated and marked by the removal of the right ventral fins.

Returns from these experiments were secured during the fishing season of 1932. Approximately 600 fish were recovered, the spring liberation returning in a ratio of about 4 to 1 to the fall liberation. Full data regarding length, locality, and date of capture, and scale samples were taken from these fish.

All of the marked fish recovered after entering the Skagit River were found in Grandy Creek where they were liberated, none being taken at the weir on Baker River. This adds additional confirmatory evidence to the theory that sockeye salmon return to their parent stream to spawn.

These data will be considered for the purpose of not only determining the proper time of liberation, but also of providing some information on the rate of mortality of these fish in the ocean and the importance of the Skagit River sockeye-salmon run to the commercial fishery of Puget Sound.

KARLUK RED-SALMON INVESTIGATION

The scientific investigations which have been carried on for a number of years at Karluk River were continued during 1932. Scale samples were collected throughout the season for the purpose of

determining the age composition of the run, which numbered approximately 1,500,000. Ten groups, consisting of fish of different ages and which had spent varying periods in fresh water before migrating to sea, were present. These were returns from 4 brood years, namely: 1925, 1926, 1927, and 1928. The majority of the run was produced by the brood years of 1926 and 1927, the former furnishing 589,000 fish and the latter 790,000. At the present time complete data are at hand as to the total return of fish from the brood years of 1921 to 1925, inclusive, but more data are necessary before any definite conclusions can be made as to the necessary magnitude of an adequate spawning reserve.

The marking experiments were continued, 59,000 seaward migrants being marked and liberated. In previous years the same mark or marks have been used throughout a season's marking. This year four marks were used: First, the amputation of the right ventral and adipose fins; second, the right pectoral and adipose; third, the left ventral and adipose; and fourth, the left pectoral and adipose. Thus the marking was divided into four separate experiments. Fifteen thousand seaward migrants were marked in each experiment except the fourth. Only 14,000 were used for the fourth experiment as the migration ended and it was impossible to obtain more. The marking was carried on from May 27 until June 22. It has been noted that the age composition of a migration changes from day to day during the migration, also the size frequency distribution of all age groups decreases as the migration proceeds, and the purpose of this added feature of the marking experiment is to determine whether or not the migrants which appear early in the migration also appear early in the season when they return as adults. These experiments will also determine whether or not a differential mortality exists between the large and small individuals of the same age group during their stay in the ocean.

The main purpose of the marking experiments is to determine the mortality of the fish during their stay in the ocean. By marking a given number of seaward migrants and then sampling the run during the years when they are returning the total number of marked fish returning may be calculated. Knowing the number of fish marked and the number returning, the mortality rate in the ocean can be determined. The problem is slightly complicated due to the fact that the fish from a given seaward migration remain in the ocean for varying periods of time ranging from 1 to 3 years. It is necessary, therefore, to sample the run during the three years following a marking experiment to determine the total return from that experiment. During the past season 159,279 Karluk red salmon were carefully examined and 1,215 marked fish were recovered of which 13 were from the marking of 1931; 1,090 were from the marking of 1930, and 112 were from the marking of 1929.

Knowing the mortality of the fish in the ocean, the number of seaward migrants resulting from a given spawning can be calculated, and as the number of fish in each spawning escapement is ascertained by means of a counting weir which is operated in the river the ratio of the number of seaward migrants to the number of fish in the escapement from which they were derived can be calculated. There is reason to believe that fluctuations in this ratio from year to year are to a large extent responsible for the fluctuations in the size of the

returns from escapements of similar magnitudes. Limnological data from Karluk Lake are collected each year, three trips having been made during 1932 for this purpose. With a knowledge of the fluctuations occurring in the ratio of the number of migrants produced per spawning fish an analysis of the limnological data should throw considerable light on the causes of the fluctuations.

This investigation is being carried on under the general direction of Dr. Willis H. Rich of Stanford University.

CHIGNIK RED-SALMON INVESTIGATION

An investigation of the red-salmon runs of Chignik River, Alaska, which is being conducted by Harlan B. Holmes, has continued along the same general program as in preceding years. One of the principal objects of this investigation has been to determine the relation between the number of spawning fish in 1 year and the resulting number of fish in the runs of future years. From this information we should learn what part of each year's run may be allowed to the commercial fishery, and what part must be reserved for spawning.

Numerous peculiarities in the composition of the runs and the life history of the fish have delayed conclusions in the investigation. At the very beginning of the investigation it was found that the scales of the fish were confusing and that confidence in age determinations based upon them would require an investigation of the life of the young fish in fresh water. As this part of the investigation has progressed many confusing irregularities in the life of the fish, which would be reflected in their scales, have been observed.

A lack of uniformity in the age composition of the catches of the several traps necessitated a careful study of methods of sampling. Preliminary results of this work have shown that extensive samples will be required for a satisfactory age analysis of the run.

There are many indications that the general run of red salmon in Chignik River is not one homogeneous population but consists of 2 self-perpetuating races represented by fish that spawn in the 2 lakes of the Chignik watershed. Although the fish of the two races differ only slightly, if at all, in anatomical characters and appearances, they have different habits. In addition to spawning in different parts of the river system, they differ significantly in time of spawning migration, length of time spent in fresh water as fingerlings, and age at maturity. There probably are significant differences in the rate of mortality of the two races.

We now have complete returns from five counted escapements. Preliminary analysis of these data indicate generally larger returns from larger escapements but there is considerable variation in the returns from a given number of spawners. A part of this variation is believed to be due to varying proportions of fish of the two races in the runs. It is hoped that when the data for the two races can be more accurately segregated the ratio of escapement to return will be found to be less variable.

Mr. Holmes, assisted by George B. Kelez, and Elmer E. Enterline spent the months of May to September at Chignik. The routine collection of data for age analysis of the run of mature fish and observations of the life of the young fish in fresh water were continued; a program of limnological observations was started; and a great part

of the fish in the commercial catch were looked over for individuals that previously had been marked as fingerlings. Only about 100 marked fish were recovered, but these few have added materially to our knowledge of the habits of the fish and the interpretation of their scales. They have shown, for example, that a great part of the fingerlings that are observed throughout the summer in the river below the lakes are not seaward migrants. They evidently move back into the lake and do not migrate until the following spring. This habit has not been observed in other rivers.

Special attention was given to determining the distinctive characters of the presumed two races of red salmon that populate the two lakes in the Chignik system. In order to permit following a group of fish of known origin an effort was made to catch and mark fingerlings in the upper lake. The unusually great number of mature fish interfered with seining for the fingerlings and only about 9,000 were caught and marked.

The run of mature red salmon at Chignik in 1932 was the largest for many years. This large run was derived mainly from 5-year fish that developed in the upper lake and 6-year fish that developed in the lower lake.

COPPER RIVER RED-SALMON INVESTIGATION

Because of the much reduced appropriation made available for biological investigations in Alaska, there were no employees of the Bureau detailed to continue the exhaustive study of the red-salmon runs of the Copper River which was begun in 1929. Seton H. Thompson, formerly engaged in this work, was detailed during the year to assist the Chief of the Alaska Division with administrative duties. In order that the work already completed would not be entirely lost, arrangements were made for the continued sampling of the daily catches of red salmon and for the collection of statistics relative to the daily catch of salmon by each fishing boat operating in the Copper River area. This work was done under the direction of Warden N. O. Hardy, and excellent data were obtained.

An examination of the spawning grounds after the close of the commercial fishing season was also undertaken by Warden Hardy, and it was concluded that the escapement, although approximately equal to that of the preceding year, was not adequate.

The study of the scales taken by random sampling of the commercial catch has been continued by Mr. Thompson at odd times, and the results of previous scale readings have been tabulated and analyzed. Twelve distinct groups are represented in the samples examined to date. These groups consist of red salmon maturing at ages varying from 3 to 7 years which have spent from 1 to 4 winters in fresh water. Two of these age groups no longer appear in the commercial catch because of the highly selective 5½-inch stretched-mesh gill net now in almost universal use in the red-salmon fishery, and one age group appears only occasionally. The two age groups no longer taken are grilse, which sampling has indicated are always males of very small size and therefore of slight importance to the industry. In all years for which samples have been fairly complete three age groups have comprised from 96 to 99 percent of the catch. Of these, the fish maturing in 5 years which have spent 2 winters in

fresh water form the predominating age group, and comprise from 78 to 82 percent of the catch. Fish maturing in 4 years after having spent 2 winters in fresh water, and those maturing at 6 years after having spent 3 winters in fresh water form the other two important age groups which appear in about equal numbers in the catch.

During the field season of 1931 data were collected for the purpose of showing whether or not the red salmon utilizing distinct spawning areas of the Copper River developed physical characteristics by which they could be identified. A comparison of such physical characters as number of vertebra, number of fin rays, number of branchiostegal rays, and number of gill rakers does not show them to differ statistically on fish from three important spawning areas. A further study of the scales of fish from these tributaries is expected to provide indications of racial differences.

A preliminary analysis of catch statistics of the Copper River indicates depletion as the result of overfishing in the period of peak production from 1915 to 1922, and the catch of recent years strongly reflects the beneficial effects of the regulations imposed in 1924 and subsequent years.

PINK-SALMON INVESTIGATION

In order to provide protective regulations for the pink-salmon run in any stream or locality it is imperative to know if the salmon hatched in that stream or locality return to it as adults. This brings up the problem of determining the degree of individuality maintained by the pink-salmon populations in different streams. The conventional manner of solving such problems has been to mark the salmon fry as they leave the streams and then observe the adult run that returns, for individuals bearing the marks. Two experiments of this nature have been completed thus far in the pink-salmon investigation by Dr. Fredrick A. Davidson—one at the Government hatchery on the Duckabush River in Washington, and one in Snake Creek at Olive Cove, Alaska. The pink-salmon fry were marked in both of these experiments by means of clipping their dorsal and adipose fins. Thirty-six thousand fry were marked at Duckabush in the spring of 1930, and 50,000 fry were marked at Olive Cove in the spring of 1931. The results from these experiments indicate that the majority of the fry originating in these streams return to them as adults. There were a few marked adults found in the neighboring streams both at Duckabush and at Olive Cove, but the degree of straying was comparatively meager.

There are over 500 streams in southeastern Alaska in which pink salmon spawn by the thousands each year. These streams vary in size from large river systems to small creeks. Some of the streams are more or less isolated along unbroken shore lines whereas others are centralized in large bays and inlets. Until marking experiments are carried on in streams of both categories, no definite conclusions can be drawn in regard to the degree of homing instinct inherent in the pink salmon.

The pink salmon in Snake Creek at Olive Cove and in Anan Creek in Bradfield Canal have been measured each summer for the past 3 years in an attempt to determine the differences, if any, in the body characteristics of the salmon composing the populations in the two

streams. The results from this phase of the work, which is generally referred to as a racial analysis, thus far indicate that the Snake Creek pink salmon differ quite distinctly from the Anan Creek pink salmon in a number of body characteristics. There are likewise a few similar characteristics between the two populations, and until further data are secured no definite conclusions can be reached. However, since the marking experiment at Olive Cove indicated that there was very little straying of the Snake Creek salmon into Anan Creek it would seem that the results from the racial analysis of these two populations are consistent with the results from the marking experiments. In this way the degree of homing instinct inherent in the pink salmon may be determined from two different types of investigations, each of which may be used to substantiate the results of the other.

STATISTICS OF THE ALASKA SALMON FISHERIES

During the past year the work of compiling and analyzing the statistics of the Alaska salmon fisheries up to and including 1927 has been completed by Dr. W. H. Rich, of Stanford University and E. M. Ball, assistant in the Alaska service. The report covering this work has been issued in several sections: Part III, dealing with the statistics of Prince William Sound, Copper River, and Bering River was published during the year; and part IV, covering the data for southeastern Alaska, was completed and submitted for publication. The statistics for the next 5 years, 1928 to 1932, inclusive, are now being worked up in furtherance of the plan to provide full information as to the state of these fisheries at 5-year intervals.

HERRING INVESTIGATIONS

During 1932 the herring investigation, under the direction of Dr. George A. Rounsefell, assisted by Edwin H. Dahlgren, submitted a report to the Bureau giving the results of experiments to determine the feasibility of tagging herring. Herring were held in a live box and tagged experimentally. It was found that silk ribbons through the opercle or body of the fish were not successful. Metal strap tags attached to the upper lobe of the caudal fin, as in salmon-tagging experiments were also not a success as the tags were a constant source of irritation causing rotting of the fin. However, herring with small metal strap tags affixed to the opercle did not show any significant difference in mortality from the untagged controls. Success was also obtained for small flat metal tags inserted into the body cavity.

Because of the tremendous numbers of herring handled by the operators it was deemed necessary to recover tagged herring from the commercial catch by mechanical means. Accordingly, a method was devised, new to fishery science, whereby the tags were recovered from the fish meal by means of powerful electromagnets. The tags themselves were made of pure nickel, which is sufficiently magnetic for the purpose and is very resistant to corrosion.

Preliminary tagging experiments in the field were made during 1932 in southeastern Alaska. Out of 1,034 opercle-tagged herring released July 27 at Port Conclusion, 10 were recovered from the 28 percent of the catch mechanically searched for tags during the

remainder of the season (to October 1). All were recovered within 12 miles of the point of tagging of necessity as the fishery was conducted around Cape Omnaney during all of the last half of the 1932 season. The time elapsing from release to capture varied from 2 to 43 days. It is planned to continue these experiments as a knowledge of the grounds occupied by each race of herring during the summer months will permit a more advantageous utilization of this resource for it will then be possible to measure more accurately the abundance of each race of herring and regulate the intensity of fishing in each area accordingly.

Work has been progressing satisfactorily on the southeastern Alaska racial data. Analyses have been made of vertebral counts, rates of growth, and a few body measurements. Although the analysis is not complete the results so far attained show the presence of several distinct stocks or populations, inhabiting the regions in the vicinities of Noyes Island, Cape Omnaney, Peril Strait, Juneau, Petersburg, and Wrangell.

Samples of herring for racial study were obtained during 1932 from Farragut Bay, Seymour Canal, and Cape Bendel, all in Frederick Sound. These samples should help materially in solving the relationship between the herring of the central Chatham Strait region and those in the "inside" waters.

The annual samples for making the usual observations on the condition of the supply and for the continuing the study of dominant year classes were collected from Prince William Sound. In the Kodiak-Afognak district large samples were obtained from Malina, Paramanof, Uganik, and Shearwater Bays.

In the Aleutian Islands district a large number of samples were again collected by Marcus Meyers from Dutch Harbor. In this area the 1923 year class has been overwhelmingly dominant since the inception of the fishery in 1928. It has varied from 82 to 60 percent of the catch from 1928 to 1931, inclusive. Since this important fishery has been so largely dependent for several years on the result of one year's spawning it is obvious that a very close watch must be maintained to see that the supply is not entirely depleted before another abundant year class appears in the catch.

ALASKA RAZOR-CLAM SURVEY

Observations on the razor-clam bed in the Prince William Sound, Copper River, and Bering River areas in 1932 were made as in past years by Paul E. Thompson of the Alaska Division, in connection with the enforcement of the clam-fishery regulation.

Sampling was continued to determine the age composition of the commercial catch and shows that more than 80 percent of the clams taken in 1932 belonged to the 5-, 6-, and 7-year-age groups. Approximately 92 percent of all clams taken in the commercial catch in 1932 were mature, but only about 44 per cent had spawned more than once as compared with more than 55 per cent in 1931. An examination of the samples of recent years shows an annual decrease since 1929 in the relative numbers of clams of the older age groups taken in the commercial fishery. This has been accompanied by an annual increase in the commercial catch of clams 5 years old, most of which have not spawned more than once.

The increased take of razor clams of minimum legal size is believed to be caused partly by the increased intensity with which operations have been prosecuted. The pack of 1932 was considerably larger than that of any recent year in spite of the fact that the open season was curtailed by about 3 weeks. To prevent further expansion of the industry which would result in serious depletion of the beds, regulations have been promulgated which prohibit the taking of a combined total of more than 1,200,000 pounds of razor clams, including shells, from these waters. This is the equivalent of 30,000 cases of 48 one-half-pound cans or approximately 65 percent of the pack prepared in 1932.

CONSERVING FISH LIFE BY USE OF SCREENS AND LADDERS

An investigation of means of improving screens at the mouths of irrigation ditches and fish ladders over power and irrigation dams was begun by the Bureau of Fisheries in 1928 and has been continued to date by U. B. Gilroy, engineer, with the advice of Shirley Baker, consultant. The principal activities in 1932 included: (1) Completion of construction of revolving mechanical screen on Jocko Canal in Montana; (2) continued operation of mechanical and electrical fish screens and fish ladders on Government projects in the States of Washington, Oregon, and Montana; (3) field inspection of sites and production of detailed designs and cost estimates on 13 mechanical screens for diversions ranging in size from 5 second-feet to 1,100 second-feet in Washington, Oregon, Idaho, Utah, and Nevada; (4) detailed design for fish ladder for upper Salmon Falls development of Idaho Power Co. on the Snake River; (5) consulting service rendered State commissions of Oregon, Nevada, Utah, Idaho, and Montana, and to the Government of New Zealand on fish screen and ladder problems; and (6) special engineering service in connection with activities of United States Bureau of Fisheries in the construction of water supplies and hatchery buildings.

MECHANICAL FISH SCREENS

The revolving mechanical fish screen developed by the Oregon Game Commission in 1921 and adopted and in use by this Bureau since 1928 continues to be the best mechanical screen which has come to the attention of the investigators. This device, fully described in previous reports, is economical in operation, requires but little attention, and when properly installed can be relied upon to give positive fish protection. Under this investigation there have been prepared detailed designs covering recommended installations of this type of screen for ditch capacities ranging from 5 second-feet to 1,435 second-feet. Such screens have been installed at Jocko Canal and the Yakima Indian project, and plans were drawn up for 13 additional locations.

ELECTRIC FISH SCREENS

The history and development of the electric fish screen has been set forth in detail in the previous reports of this division. During 1932 the Bureau operated electric screens on the Government projects in the Yakima country and on the Kvichak River, Alaska. However, as set forth in the report for 1931, owing to public antagonism which

is likely to develop when even a very few fish are killed or stunned by electrified water, it is not the policy of the Bureau to recommend the electric screen for general use.

Sunnyside electric screen.—The Sunnyside Canal (capacity 1,500 second-feet), main diversion of the Yakima project of the Reclamation Service, diverted water from March 14 to October 10, inclusive. During the period of maximum irrigation demand which coincides with the chief period of migration of fish, the flow of the canal exceeded 1,000 second-feet. This canal is the lowest screened diversion on the Yakima River. This year operating conditions were much more favorable than during the preceding season, there being a large overflow at the dam to serve as a bypass for the fish. In the past during flood, drift has piled up against the Sunnyside headgates interfering with the electrodes. Permanent facilities for handling such drift have now been provided through the cooperation of the Bureau of Fisheries and the Reclamation Service in the installation of a mechanical winch.

The operation of the Sunnyside electric screen was uninterrupted throughout the irrigation season. Other electric screens were operated successfully at the Wapato Canal, Old Indian Canal, Tieton Canal, Naches Power House in Washington, and the Kvichak River in Alaska.

Kvichak electric screen.—The Kvichak River is considered the greatest red-salmon stream in the world. This electric screen is used in connection with the counting of the escapement of salmon up the river to the spawning grounds. This year the Kvichak screen was installed at a point approximately 12 miles upstream from the site used in 1930. At this new location 2 islands, each about one half mile long, divide the river into 3 channels. The electric screen was installed across the central channel at the lower end of the Islands. This central channel, about 660 feet wide, is too deep and swift to permit the installation of the usual type of wooden rack and counting gates. The racks closing the side channels were located at the upper end of the islands.

The screen consisted of an upstream row of electrodes of ⅜-inch galvanized chain properly weighed and suspended in the water from a piling support. The other side of the electric circuit was connected to a 2½-inch diameter galvanized-iron pipe paralleling the chain electrodes at a point 20 feet downstream. This pipe electrode was supported from a row of piling and so suspended as to clear the bottom of the channel by about 1 foot. Power was furnished from a 9-kilowatt, 125-volt, 60-cycle alternating-current generator driven by a 15-horsepower Fairbanks-Morse gas engine. Approximately 80 volts was found to be the most effective potential at the screen and at this voltage the installation drew approximately 50 amperes.

The action of the electric screen in diverting salmon away from the central channel and directing them up the side channels to the counting weirs was practically 100 percent effective. During the period from June 28 to August 5 the actual count of salmon passing through the Kvichak weir was as follows: 5,064,014 red salmon, 5,753 kings, 1,020 chums, and 200 pinks. No fish were observed to pass through the electrified area, and they showed no hesitation in being diverted to the side channels. Throughout this enormous run less than 200 salmon were found to have been killed by the electric

current, and these electrocutions were confined to an area where an eddy current prevented fish from escaping to safe water after contact with the electric current.

This year's success with the Kvichak screen illustrates the great importance of proper location, for the same screen installed in 1930 at a downstream site failed to function as a diverter. It is felt that the construction of the wooden racks in separate channels well removed from the electrified area has offered distinct advantages.

Check of fish in Yakima ditches.—This year, as in previous seasons, a comprehensive check on fish left stranded in the Yakima ditch systems was conducted at the end of the irrigation period. These final checks together with special checking operations and close observation of fish migration in the canals and rivers were conducted throughout the summer and fall, and as in previous years, the count indicated that the Tieton electric screen operates with high efficiency. The effectiveness of this screen is brought out strongly by comparison with fish conditions on the Selah-Naches Canal (capacity about 300 second-feet) which diverts water from Tieton River under conditions similar to those existing at the Tieton diversion. A complete check of fish left stranded in the Selah-Naches system showed, by actual count, 855 salmon, 188 trout, 1,027 whitefish, and 129 culls, with an estimated additional total of 450 fish of all kinds that had escaped seining.

FISH LADDERS

The Bureau has installed and now supervises the operation of fish ladders at Sunnyside Dam of the Reclamation Service, Yakima River, Wash.; at Wapato Dam of the Indian Service, Yakima River, Wash.; and at Sprague River Dam of the Indian Service on Fort Klamath project, Oregon. These installations are all of ample design and of substantial reinforced-concrete construction. All reliable observations point to the thoroughly satisfactory operation of these ladders in passing the fish migrations of 1932.

Upper Salmon Falls ladder.—The fish ladder for the upper Salmon Falls Dam of the Idaho Power Co. was designed early in 1932, and is located on the Snake River near Hagerman, Idaho. The construction of this development, which will raise the water approximately 16 feet, was started in the summer of 1931, but the work has been temporarily suspended due to power market conditions. The power company has worked in close cooperation with the Bureau and the design of the dam includes provisions for the construction of this fishway as an integral part of the dam structure.

Rock Island fish ladders.—In previous reports this major power development of the Puget Sound Power & Light Co. on the Columbia River near Wenatchee, Wash., has been described in detail. The summer migrations of 1932 provided the first test of the two huge fish ladders installed according to the specification of the Bureau of Fisheries and the State commissions of Washington and Oregon. Throughout the summer there was an abundance of overflow at the dam.

The west channel ladder, constructed 800 feet downstream from the location originally proposed, possesses marked advantages over the originally planned structure being composed largely of pools excavated in solid rock and possessing better entrance facilities.

The requirement for fish protection as stated in the project license from the Federal Power Commission provides for the construction of a third ladder if this structure appears necessary. All available data indicate that the two ladders now built functioned satisfactorily in passing the 1932 fish runs, and it would seem but fair and proper that no demand for the expensive construction represented by a third ladder should be made unless and until future reliable observations established the actual need of this structure and make possible an intelligent specification for its location and design.

Ariel development.—At this high head power development on the Lewis River in Washington the Inland Power & Light Co., in lieu of a fish ladder which would have been impractical at a dam of this height, has provided for the trapping of the upstream migrating salmon at the power house tailrace and the ripening, spawning, and rearing of these fish on an extensive scale. These provisions and operations have been described in detail in our previous reports. The fish protective works have now been completed and an agreement entered into between the company and the State of Washington. In this agreement compliance with the requirements for fish protection is acknowledged, the hatchery property and equipment is deeded to the State, and provision is made for an annual payment to the State of Washington for the operation of the hatchery. The Bureau of Fisheries has now formally approved of the agreement, thereby acknowledging the company's fulfillment of the requirements for fish protection as set forth in Federal Power Commission's license for the project. The feature of particular interest to this Bureau is the operation of the fish trap and the mechanical lifting device located over the power house tailrace. More than $57,000 was invested in this equipment. Several runs of salmon and steelhead have demonstrated the effectiveness of this type of equipment. It is believed that the methods here employed constitute the most progressive steps yet taken for handling upstream migrating fish at high dams.

FISH PROTECTION ON GOVERNMENT PROJECTS

In the spring of 1932 the Reclamation Service started construction of the Prosser power development which involves the diversion of 1,100 second-feet of water from the Yakima River near Prosser, Wash. At this project the dam was already provided with a satisfactory fishway, but there is a need for a screening device to conserve the downstream migrating salmon and steelhead.

At the present time the Reclamation Service is also constructing a dam on the Cle Elum River in the Yakima watershed which will raise the water surface of the river 140 feet and store 435,000 acre-feet of water. At this dam a fish ladder will not be feasible and neither the type of construction nor the plans for operating the reservoir favor the mechanical handling of fish and, if constructed, such mechanical equipment would be very costly.

Following thorough field investigation and conferences with the engineers of the Reclamation Service at Denver, recommendations of the Bureau of Fisheries were that, in lieu of attempts at costly mechanical handling, the Reclamation Service should allot to the Bureau 5,000 acre-feet of storage each year to be used specifically for fish

protection, and that a necessary fund be provided for racking the Cle Elum River below the dam site. As in the case of the Prosser screen, the field services of the Bureau of Reclamation and the Bureau of Fisheries cooperated fully to obtain this means of protection, but the matter came to a standstill before the higher authorities of the Reclamation Service, the position being taken that nothing could be done as the appropriation for the project carried no specific item for fish-protective work.

Need for a definite policy.—The experience of the Bureau of Fisheries in seeking to obtain very necessary fish protection at the Prosser power development and at Cle Elum Dam has brought out strongly the necessity for the determination of a definite policy between the Departments of Commerce and Interior which will provide the basis for securing proper safeguards to fish life on those Government projects where anadromous fish are affected. Until such a policy is adopted no tangible results can be secured by the field services. Furthermore, it should be provided that on streams where anadromous fish are affected all plans for new construction by the Department of the Interior be submitted to the Commissioner of Fisheries for recommendations as to fish protection, exactly as is now done in the case of private concerns seeking permits for power developments before the Federal Power Commission. Such a procedure would allow for economical planning of the fish-protective works, would permit of the project appropriation carrying a definite item for fish protection, and would allow the construction of the recommended devices along with the building of the project.

GREAT LAKES FISHERY INVESTIGATIONS

Investigations of the important commercial fisheries of the Great Lakes during the past year have been concerned almost wholly with the abundance and distribution of the various species of food fishes and the effects upon the fish populations of the various types of commercial fishing gear. Although the yield of the commercial fisheries in these waters has been maintained in the aggregate for several decades, it is generally known and recognized that depletion of the important species is occurring with greater rapidity in some lakes than in others, and that total production has been maintained by the substitution of less valuable species for the ones that are more valuable and better known. Lacking sufficiently detailed statistics of the fishery yield, in the States bordering these waters, the fact of depletion is taken for granted and no serious attempt has yet been made to study the fishery from a quantitive standpoint, tracing variation in yield as has been done with such success in the marine fisheries of this country. In recent years several of the Great Lakes States have adopted an adequate system of fishery statistics sufficiently detailed to measure variations in abundance of the fish stock. Until these records have accumulated, however, for a sufficient period of years to make their analysis worth while, the efforts of the Bureau's technical staff, under the direction of Dr. John Van Oosten, are directed toward the correction of abuses in the commercial fishery and especially the reduction of the tremendous wastage of immature and undersized fish that annually reaches impressive proportions.

Virtually all of the field work conducted on the Great Lakes in 1932 was confined to Lake Michigan (including Green Bay) and Lake Huron. One investigator carried on some field work on Lake Erie during the period, April 5–20. No new projects were started in 1932 and all the major field investigations begun in years previous to 1932 were brought to a close. The completion of these field investigations was made possible only by the financial support given by the States of Michigan and Wisconsin. The Bureau continued its cordial relations with the various Great Lake States and provided them with considerable information and scientific data that were used as a basis in the consideration of new regulations o the commercial fisheries. The Bureau has been particularly active in its endeavors to secure uniform legislation on the Great Lakes especially on Lakes Erie and Michigan. This is evident from the fact that during the past year Dr. Van Oosten attended some 15 conferences with State officials and fishermen for the purpose of presenting data and discussing or proposing new fisheries regulations.

In this connection it is of extreme interest to report the establishment of a permanent advisory committee whose primary duties are to consider and study all uniform legislation proposed for the fisheries of Lake Erie and to make recommendations and give advice to the departments of each State fronting Lake Erie and to the Province of Ontario. This Lake Erie Advisory Committee is composed of one representative from each participating State, the Province of Ontario, and the Bureau of Fisheries. Dr. Van Oosten was appointed chairman of this committee. The committee met twice in 1932 and through it the various States and the Province of Ontario were enabled to come to an agreement, making uniform certain proposed regulations on Lake Erie. The establishment of this committee is in line with the new policy advocated by the Bureau whereby the fisheries of the Great Lakes are considered for each lake seperately and only by those commonwealths that have a direct and controlling interest in them. The Bureau believes that this new policy will lead to greater and better results in the establishment of uniform laws on each lake.

Some progress has been made in 1932 in the compilation of the statistics of the catch of the Great Lakes in such form as to show the catch per unit of gear per unit of time. These statistics permit a study of the correlation of the catch and fishing intensity and thus enable a determination of the real trend in abundance of the various species of fish in the different lakes. The statistics collected by the State of Michigan have been made the starting point in this work. Those collected in 1927 and 1928 already have been worked up by districts for the four lakes controlled by Michigan. The statistics collected in later years will be compiled as rapidly as funds and time permit.

Through the courtesy of the Michigan Department of Conservation motion pictures were made showing the various phases of research work conducted by the Bureau on the Great Lakes. These pictures show in great detail the various field operations carried on by the *Fulmar* in the Lake Michigan investigation as well as the work conducted in the laboratory at Ann Arbor. This film will be one of a series of educational films produced by the State of Michigan.

The Great Lakes staff has contributed to nearly every issue the feature article of a newly established monthly magazine devoted exclusively to the commercial fisheries of the Great Lakes.

CHUB FISHERIES OF LAKE MICHIGAN AND GREEN BAY

The cooperative studies on the chub fisheries of Lake Michigan carried on in 1930 and 1931 (for details see report for 1931) were resumed in 1932. The Bureau's vessel *Fulmar*, employed for the work, was placed in drydock for repairs early in April and left Sturgeon Bay, Wis., on April 19 for the first cruise of the season. From April 19 to May 31 the work was restricted to Green Bay (for details of problem see report for 1930) and from June 1 to September 13 operations were limited to Upper Lake Michigan north of Frankfort, Mich., and Sturgeon Bay, Wis. The 1930 and 1931 operations had been restricted to that part of the lake which lies south of this line. During the 1932 season the *Fulmar* covered a total distance of some 6,096 statute miles and lifted some 161 miles of chub gill nets at 67 different stations. Fishing operations were conducted out of the ports of Marinette, Wis., and Escanaba, Mich., on Green Bay, and out of Manistique, Charlevoix, and Frankfort, Mich., on Lake Michigan. As was the case in previous years, nets were fished simultaneously out of those ports located on the same body of water.

In 1930 and 1931 five sizes of gill-net mesh were employed in Lake Michigan proper, but in 1932 only three sizes were used there, viz: 2½, 2⅝, and 2¾ inches. The 2⅜- and the 3-inch mesh were eliminated, as previous work showed that neither of these two sizes of meshes could be recommended for use in the chub fisheries. In Green Bay, however, the 2⅜-inch mesh was fished in addition to the 2½-, 2⅝-, and 2¾-inch. The lifting and setting of approximately 2 miles of gill nets, 7 nets of each size mesh, constituted 1 day's fishing operations in upper Lake Michigan. Some 3,276 lake trout that weighed 2,649 pounds and some 32,846 chubs that weighed 14,619 pounds were taken in upper Lake Michigan, while some 2,845 lake trout, 2,873 lake herring, and 1,367 chubs that weighed 1,616, 1,289, and 585 pounds, respectively, were taken in Green Bay. Biological data were secured for each individual fish, to the extent that time permitted, on the following: Length, weight, sex, maturity, scales (chubs only), stomachs (lake trout and lawyers only). A large series of chubs and lake trout were preserved for future study in the laboratory.

In addition there were collected 173 plankton samples, 91 samples of bottom organisms, and 69 soil samples for geological analysis. Temperatures were recorded whenever weather permitted. The study of surface currents by means of drift bottles was continued from 1931. In 1932 some 462 bottles were released and of this number 304 have been recovered to date, yielding a percentage return of 65.8, which is approximately 2 percent higher than the returns of 1931.

The data of the Lake Michigan chub-net investigation have been summarized for the 3 years, 1930 to 1932, and conclusions pertinent to legislative recommendations have been drawn and submitted to the conservation departments of Michigan and Wisconsin. The data are undergoing further analysis with a view toward detailed presentation in published form. Some of the outstanding conclusions follow:

1. The amount of destruction of baby lake trout (average weight about 12 ounces) by chub nets cannot be reduced by changing the mesh in these nets to a size that would still be suitable for the purpose of taking chubs. The adoption of any one of the three sizes of mesh (2½, 2⅝, and 2¾ inches) now legally employed in the different States fronting Lake Michigan will not alter the destructiveness of chub nets to small lake trout.

2. Chubs show a sensitive reaction to the size of mesh in gill nets in the number of fish taken per net. On the average, the number of chubs taken in the 2½-inch mesh gill nets is reduced by 38 percent with an increase in mesh to 2⅝ inches and by 62 percent with an increase in mesh to 2¾ inches, or in terms of weight in pounds the percentages of reduction are respectively 36 and 61 percent. With an increase in size of mesh from 2⅝ to 2¾ inches there is a corresponding decrease of 39 percent in both the number and weight of chubs.

3. Baby lake trout were found to be about 2.7 times as abundant in the Michigan waters of Lake Michigan as in the Wisconsin waters of this lake. In Michigan the sale of all baby lake trout is prohibited; in Wisconsin the sale of those taken in gill nets is permitted and, as a consequence of this, a large market has been developed for these immature fish. It is believed that this practice of selling these baby trout in Wisconsin is primarily responsible for the difference in its abundance in the two States. It has been recommended, therefore, that suitable legislation to prohibit or at least to curb the sale and transportation of these immature fish be enacted in those States that have no such restrictions at the present time.

4. Chubs were found to be about 2.7 times as abundant in the Michigan waters of Lake Michigan as in the Wisconsin and Illinois waters of this lake. It is believed that this difference in abundance is caused primarily by the difference in the size of mesh employed for chubs in the three States. Illinois permits a 2½-inch mesh, Wisconsin a 2⅝-inch mesh, and Michigan a 2¾- to 2⅞-inch mesh. It is common knowledge among the fishermen that the chubs are steadily decreasing in abundance in Lake Michigan especially along the Wisconsin shore. It is absolutely essential, therefore, that fishing intensity be decreased if the chub fisheries are to be saved. One of the most practical ways to do this is to increase the size of mesh in chub nets to a minimum of 2¾ inches. Such a minimum in size of mesh would, according to our data, reduce the catch of chubs about 39 percent in Wisconsin where most of the small mesh chub nets are fished. If such reduction in catch is not sufficient to enable the chubs to maintain the desirable level of abundance further restrictions, such as a closed season, will be necessary. An increase in the size of mesh would also give additional protection to the smaller chubs, would increase the average size of chub produced for the market, which increased size would in turn raise the price per pound paid the fishermen.

DEEP TRAP NETS OF LAKES HURON AND MICHIGAN

The deep trap-net investigation, begun in 1931 (see report for 1931), was resumed on May 7, 1932, and completed on October 20, 1932. The State of Michigan again cooperated with the Bureau by furnishing 3 field assistants and 2 automobiles for transportation. Deep trap and pound-net lifts were studied at Harbor Beach, Bay Port,

East Tawas, Ossineke, Alpena, and Cheboygan on Lake Huron and at Bervort, Epoufette, Naubinway, Cozy Harbor (Scotts Point), and Manistique on Lake Michigan, and at Escanaba and Marinette on Green Bay.

The data collected during the 2 years have been compiled and analyzed and show briefly the following facts that are pertinent to legislative recommendations:

1. The number of deep trap nets employed was larger in 1932 than in 1931.

2. The average number of both legal and illegal whitefish per lift was less in 1932 than in 1931 at those ports where lifts were observed from nets with the same size mesh set in the same depth of water and lifted on comparable dates in the 2 years.

3. Both the average total length and the average weight of the legal sized whitefish decreased slightly in 1932 as compared with corresponding averages in 1931.

4. The distribution by depth of water of both legal and illegal sized whitefish was practically the same for the 2 years—the illegal sized fish being most numerous in water from 81 to 109 feet in depth, while the legal sized fish were most numerous in water deeper than 110 feet.

5. The deep trap nets now in use have lifting pots with meshes ranging from 3½ to 5 inches in length, stretched measure.

6. In 1932 a wholesale transfer of deep trap nets occured from certain fishing grounds, long famous for its whitefish production, to new grounds, due to the paucity of whitefish on the old established grounds.

On the basis of the above facts the following regulations were proposed for the fishing of deep trap nets in Michigan waters: (*a*) Limit the depth of water in which these nets may be fished to 80 feet and less; (*b*) require the minimum size of meshes in the lifting pot to be 4½ inches in length, stretched measure, as found in use permitting a smaller mesh, not to exceed 2¼ inches, in one side of the pot for the purpose of shoaling fish.

STUDIES IN LAKE ERIE

Yellow perch.—A preliminary paper was published by Frank W. Jobes on the age and growth of the yellow perch of Lake Erie. The study was based on some 1,179 specimens taken in 1927 and 1928. Mr. Jobes found that the ages of these perch ranged from 1 to 6 years and that the year class of 1926 dominated the catch in both 1927 and 1928. Males and females grew in length at approximately the same rates during the first 4 years, with the exception that the females of the 1925 year class apparently grew significantly faster than the males in their third year—the summer of 1927. The most rapid growth occurred during the first 2 years with a sharp decline in growth rate during the third and a more gradual decline during the fourth year of life. The sharp decline in the growth rate during the third year may be associated with the attainment of sexual maturity. The yellow perch of Lake Erie require 4 years to reach a total length of 9 inches, the highest legal length limit for perch on the Great Lakes.

Other species.—Age determinations and length computations from scales have been completed for all the ciscoes and whitefish collected on Lake Erie during the years 1927 to 1931, inclusive. During the

period, April 5–20, 1932, biological data and scales were secured from some 1,329 yellow pike perch, 1,924 saugers, and 133 yellow perch from Lake Erie—a total of 3,386 fish. These data were necessary to complete the series collected in previous years and to make possible a study of the complete life history of the pike perches of Lake Erie.

Limnology.—No field work was done in 1932 on the limnology of Lake Erie, but Dr. Stillman Wright was assigned to the compilation of the large amount of data collected by the cooperative survey (see report for 1931), and to the preparation of the final report which is now nearly ready for submission for publication.

COOPERATIVE INVESTIGATIONS, INTERIOR LAKES OF WISCONSIN

In the cooperative investigations of the physical and chemical conditions in lakes of northeastern Wisconsin conducted by the Wisconsin Geological and Natural History Survey and the Bureau of Fisheries the very active program of investigation by the personnel of the State Survey was conducted by a field party of 11 biologists and chemists under the direct supervision of Dr. A. E. Birge and Prof. Chancey Juday at the Trout Lake Laboratory from June 27 to September 12, 1932. A study of fish life in these lakes was conducted by Dr. Ralph Hile and one assistant for the Bureau of Fisheries.

Materials obtained for the study of the age and growth of the fishes of the lakes of northeastern Wisconsin included data from 8,007 specimens. Of this number 1,407 ciscoes, 724 perch, and 329 rock bass were preserved. The preserved ciscoes are being used in a morphometric study bearing on changes of form with growth and on the question of the existence of local races of that species. The need of more exact formulas for the calculation of growth of the perch and rock bass from scale measurements has made necessary a detailed study of the change of the body-scale ratio with increase in age and size. The collections were again taken from the six lakes selected as "types."

With the 1932 collections of age and growth materials pertaining to the perch, cisco, and rock bass, the field work of this phase of the cooperative study of the lakes of northeastern Wisconsin is completed. Reports by Dr. Hile of the Bureau on the age, growth, and morphometry of the cisco and by Edward Schneberger of the Wisconsin Geological and Natural History Survey on the age and growth of the perch will be completed in the near future.

In general, the major part of the limnological investigations conducted by the Geological and Natural History Survey was done on the six lakes which were selected for an intensive study of the fish fauna, with the exception of observations on the penetration of solar radiation into the various lake waters; several other lakes were included in the latter investigations.

In the chemical work, quantitive determinations of the dissolved gases, phosporous, nitrates, and hydrogen-ion concentration were made on the 6 lakes from which fish were obtained for growth studies and 2 additional lakes. No noteworthy chemical changes from previous years were observed in these lakes.

A special study of the hydrogen-ion concentration of the water was made in a number of lakes. There was a question regarding the reliability of the pH readings on samples obtained from the deeper

waters of a lake. That is, it was not known whether changes in temperature and hydrostatic pressure due to hauling a sample to the surface from a depth of 25 meters, for example, made any difference in the hydrogen-ion concentration of the water. In order to answer this question, a quinhydrone outfit with a calomel electrode was constructed so that readings could be taken in situ at the various depths. Results obtained with this instrument showed conclusively that hauling a sample to the surface from a depth of 33 meters for the pH determination did not have any appreciable effect upon the hydrogen-ion concentration, even when the sample contained a considerable quantity of free carbon dioxide.

In order to correlate the work on the penetration of solar energy into lake waters with some of the biological phenomena, observations were made on the photosynthetic activities of some phytoplankton algae and on one of the large aquatic plants. These experiments show clearly that the color of the water has an important bearing on the depth at which photosynthesis can take place.

A qualitative and quantative survey of the large aquatic plants was made on 5 of the smaller lakes during the summer and qualitative observations on 11 others. Material was also collected for a study of the ecological anatomy of the plants growing under different soil conditions and this investigation is now in progress.

Phosphate fertilizer was added to the water of Weber Lake in order to determine whether the phytoplankton crop of this lake could be materially increased by this means. This experiment demonstrated that the phosphate content of a lake of this size can be greatly increased during a period of 3 or 4 months at a cost of about $15 for phosphate material.

The plankton crop proved to be a little more than 10 percent larger in 1932 than in 1931; but this small increase can hardly be regarded as significant, especially since some of the other lakes on which regular plankton observations were made, showed larger increases without any phospate treatment whatever.

Plankton observations were made regularly on the six lakes. The average quantity of organic matter in the centrifuge plankton varied from 85 to 140 milligrams per cubic meter of water on a dry basis. The smallest quantity reported, however, was 50 percent larger than in the previous year. From these figures and from the known areas and volumes, the standing crop of plankton per unit of area in various lakes is computed.

Approximately 8,000 fish were collected during the summer for the purpose of studying their rate of growth. The alimentary tracts of 2,500 fish were examined for the purpose of determining the quantity and kinds of food eaten. Approximately 30 percent of the specimens contained no food, thus leaving 70 percent for analysis. The great majority of those containing food consisted of the following: Perch, 796; rock bass, 508; bluegills, 82; ciscoes, 283; and suckers, 99. The remainder consisted of whitefish and various species of game fish.

The internal parasites of 1,823 fish and 64 birds were studied during the summer. A small trematode larva was found in the eyes of 96 percent of the perch and 92 percent of the rock bass from Muskellunge Lake and in all of the perch and rock bass from Nebish Lake. Only 20 percent of the perch and 24 percent of the rock bass from Trout Lake harbored flesh parasites, while these trematode

larvae were found in the flesh of 55 percent of the perch and 94 percent of the rock bass of Muskellunge Lake and in 89 percent of the perch and 100 percent of the rock bass from Nebish Lake. Intestinal trematodes were found in 79 percent of the rock bass of Muskellunge Lake and in 62 percent of those from Trout Lake; only 10 percent of those from Nebish Lake were infested with these parasites. Nematodes, cestodes, and Acanthocephala were present in many of the fish also, but usually not in such a large percentage of them.

OYSTER INVESTIGATIONS

Under the direction of Dr. P. S. Galtsoff, investigations concerning various problems of the oyster industry were carried out in New England and the North Atlantic States (Vineyard Sound, Buzzards Bay, and Long Island Sound); South Atlantic States (Beaufort, N.C., South Carolina, Georgia, and west coast of Florida); and on the Pacific coast in Washington and California. The selection of specific projects of study in different sections of the country was governed both by the local conditions and most urgent needs of the industry. Thus, in New England and the North Atlantic States, where previous work of the Bureau materially helped in the solution of the problem of propagation of the oyster, the main efforts were directed to a study of the methods of growing, fattening, and improvements of the nutritive quality of the oysters. On the other hand, in the South Atlantic States where the depleted state of the natural oyster reefs threatens the existence of the industry, principal attention was given to the methods of restocking and maintaining the productivity of the bottoms. On the Pacific coast the work consisted in studies of the cultivation and development of the native Olympia oyster.

INVESTIGATIONS IN NORTH ATLANTIC STATES

In cooperation with the Shellfish Commission of the State of Connecticut the Bureau has established a field laboratory on State property at Milford, Conn., and planted several thousand bushels of 3-year-old oysters on a 6-acre tract of bottoms in Long Island Sound set aside for that purpose by the Shellfish Commission. Oysters for planting were donated by the Mansfield Co. The authorities of Yale University cooperated in this project by granting to the Bureau's investigator the privilege of using the laboratory facilities of the university. Boats for this work were furnished by the State Shellfish Commission and by the Connecticut Oyster Farms Co.

Since April 1932, field observations at Milford and vicinity have been carried out by V. L. Loosanoff and Dr. P. S. Galtsoff. The results obtained during the 9-month period show that oyster meats undergo important chemical changes. During the early summer the glycogen content gradually decreases reaching a minimum just before spawning. The discharge of eggs and sperm is followed by a considerable loss of solids and corresponding increase in the water content of the meat. During this period, which lasts about 2 weeks, the water content increases from about 75 percent to over 90 percent. It is obvious that during this period the food value of the oysters is very low. The period of spawning is followed by a period of rapid accumulation of glycogen which before the onset of cold weather

reaches a very high figure. On the best grounds oysters analyzed in November contained as much as 9 percent of glycogen (fresh basis). After the temperature of the water drops below 42° F. oysters begin to hibernate; their meat loses weight, although the shells continue to grow and the total weight increases.

Analyses of the metal content (iron and copper) indicate a great variability in the amounts of heavy metals stored by the oysters in different localities and during different seasons. On the basis of the information obtained by the investigators it seems possible to regulate the metal content of the oyster by proper methods of transportation and cultivation.

Food of the oyster.—Changes in the chemical composition of the meats are brought about by seasonal changes in the composition of the sea water and in the natural food of oysters. This problem has been studied by Dr. Galtsoff, Mr. Loosanoff, and Mr. Smith, both in the field and in the laboratory. Large numbers of diatoms which constitute the principal food of the oyster were obtained from the oyster bottoms and were raised in pure cultures under controlled conditions. The experiments give considerable information regarding the methods of propagation of these important forms and their value as a food of the oyster. It is expected that on the basis of these experiments, a method may be found whereby oyster farms could be supplied with the most suitable food for oysters and unproductive oyster bottoms converted into fertile grounds.

Japanese oyster.—During the last year, oyster growers made many inquiries as to the possible effect on the native stock of the importation of the Japanese oyster. In order to answer this important question a series of experiments was performed at Woods Hole by Dr. Galtsoff and R. O. Smith. They show that the Japanese species, *Ostrea gigas*, easily interbreeds with the native oyster, *Ostrea virginica*. It is therefore, obvious that the presence of the Japanese species on the Atlantic coast will result in the interbreeding of the two oysters. It is, however, impossible at present to state whether the resulting hybrids will be in any respect better or worse than the native species.

Control of starfishes.—The work on the control of the starfish by checking its propagation and destroying the young stars by application of copper sulphate solution was carried out in Buzzards and Narragansett Bays by Louise Palmer. After September 1, on account of lack of funds, the project was discontinued. The Bureau, however, is fully aware of the dangerous situation caused by an extraordinary increase in reproduction of this enemy of the oyster. During the last two summers very heavy spawning of starfishes was observed both in Buzzards and Narragansett Bays. It is expected that the oyster beds in these bodies of water will suffer considerable damages from the depredations of this pest.

SOUTH ATLANTIC OYSTER STUDIES

Practical experiments in oyster farming and investigations of conditions on the natural oyster beds were conducted from North Carolina to Florida under the supervision of Dr. H. F. Prytherch. Laboratory and field studies of oyster spawning and setting were made at eight representative coastal stations in this section and at the United States Fisheries Laboratory at Beaufort, N.C., which serves as headquarters

for this work. In cooperation with the various State Shellfish Commissions, oyster farming operations were carried out on a small commercial scale for the purpose of determining and demonstrating the most efficient methods for oyster culture in each particular region. The results of these experiments and field surveys of natural oyster beds are described briefly according to the States in which these operations were conducted.

Experiments in North Carolina, South Carolina, and Georgia.—Oyster spawning occurred almost simultaneously throughout this section during the first week in May or about 2 weeks earlier than in 1931. A fairly heavy set was obtained by June 1 on the various spat-collecting devices planted on the tidal flats. Brush poles, cement-coated paper tubes, and mats were found to be of practical value for gathering seed oysters. The myrtle and oak poles (2 to 4 inches in diameter and 3 to 4 feet long) collected from 75 to 250 seed oysters per pole. On the paper tubes an average yield of 300 seed per tube were obtained while the expanded mat collectors gathered from 500 to 3,000 seed oysters each. By the use of poles and tubes it is possible to utilize thousands of acres of barren mud bottoms for collecting and growing seed oysters. The mat collectors proved to be particularly suitable for planting over oyster beds or on shell bottoms and are so designed as to prevent crowding of the seed, allow ample room for growth, and eliminate the detachment operations required by other types of collectors. In several localities plantings of seed oysters and shells were made to demonstrate these phases of oyster farming and show the value of such methods for the rehabilitation of barren bottoms and natural oyster beds.

At the Beaufort laboratory, research was continued on the problem of improvement in oyster-shucking methods and the preparation of this sea food for market.

In the marketing of oysters the raw-shucking trade is of greatest importance both as regards the quantity of oysters handled and number of persons employed. At the present time approximately 60 percent of oysters produced for the fresh trade are shucked before marketing. The total quantity of oysters marketed raw amounts annually to nearly 5,500,000 gallons for which it is estimated over $1,500,000 are expended each year for shucking alone.

Experiments conducted by Drs. Vera Koehring and H. F. Prytherch, dealing particularly with this phase of the industry, show that oysters can be easily narcotized by chemical means so as to produce automatic opening of the shell and facilitate removal of the meats. The preliminary studies and fundamental aspects of this process are described in Investigational Report No. 15 of the Bureau of Fisheries.

Subsequent research has shown that oysters receiving mechanical stimulation previous to their immersion in the narcotizing solution will be open and ready for shucking in but a fraction of the time required previously. By simple mechanical procedures, such as dropping the oysters on a hard surface or hitting the shell a single sharp blow, it has been possible in numerous experiments to completely narcotize 100 percent of the oysters in a period of from 10 to 30 minutes. This has greatly increased the practical value of such opening operations as from 6 to 12 hours were required previously to accomplish the same results. This improvement in the method makes it from 30 to 50 percent cheaper as a smaller amount of acid is employed and the

narcotizing solution can be used for several consecutive batches of oysters.

Oyster investigations in Florida—Three surveys were made by Dr. Prytherch of the oyster beds and condition of the industry in Apalachicola Bay and Choctawhatchee Bay on the west coast of Florida. Examinations of 11 of the most important bars in the former locality in January showed no evidence of depletion and an abundant supply of seed and adult oysters. Overcrowding of oysters was evident on most of the natural bars which should be corrected by transplanting a certain proportion of the culled or undersized oysters to adjacent firm bottoms where better conditions for feeding and growth are available. In the fall serious destruction of oysters was reported in St. George Sound on the natural and planted beds in the vicinity of Porters Bar. Studies made there in November showed that 50 to 75 percent of the oysters had been killed by a parasitic flatworm or so-called "leech." From 1 to 4 flatworms were found in each affected living oyster or in the empty shells of recently killed specimens. Similar outbreaks of this parasite have occurred previously at Tampa, Cedar Keys, and Indian River Inlet during dry warm seasons and similar conditions were apparently responsible for the high mortality of oysters in St. George Sound.

A new and promising territory for the production and cultivation of oysters was found in Choctawhatchee Bay. The recent formation of a new inlet to the Gulf of Mexico has greatly increased the salinity of the water and produced excellent conditions for oyster growth and reproduction. Experimental plantings of seed oysters and shells will be made here during the summer of 1933 to determine the most practical measures for increasing the production of the natural beds and the development of oyster culture on barren bottoms.

PACIFIC COAST OYSTER STUDIES

Oyster investigations in the State of Washington.—The experimental study of the cultivation of Olympia oysters, begun in 1931, in cooperation with the Washington State Department of Fisheries and Game, was continued during this year.

An intensive study is being made of the spawning and setting of larvae in the two most important oyster producing bays in the Olympia region. For this purpose, wire bags filled with large shells were planted twice a week in certain typical dikes. Each bag of shells was allowed to remain in the water 7 days, when it was brought into the laboratory and counts made of the number of spat which had been caught. In Oyster Bay the setting season may be divided distinctly into two parts. The first setting period began on June 26, reached its peak on July 5, and ended about July 25, at which time a second setting period started. The peak of this period was reached on August 25 and setting practically ceased by August 31. From this time until the middle of October, periods of constantly decreasing abundance of setting occurred. At the peak of the first set, something over 6,000 spat per day per bag of shells were taken, while at the peak of the second set, approximately 7,500 were caught. Oyster grounds down the bay from the great mass of oyster beds gave results entirely similar, except that the total set was only about one fifth as great as that above described.

For some reason, in Mud Bay the results obtained were entirely different, although the conditions of salinity and temperature in the two bays differ only very slightly. In Mud Bay there were four relatively small waves of setting. The duration of these was as follows: (1) July 6 to 23, (2) July 24 to August 5, (3) August 13 to 23, and (4) August 24 to 30. In the same order, the number of spat obtained per bag of shells during the peak of each of these periods was: 1,500, 1,200, 500, and 400. While in Oyster Bay the larvae continued setting up until about the middle of October, in Mud Bay after the first of September practically no further set was obtained. The method of planting cultch at present employed by the oyster growers is apparently based on the assumption that only one setting period normally occurs, for cultch is always planted in June. During two seasons it has been found that in Oyster Bay the second period of setting taking place in August is as great as the first. It has been suggested that oyster growers attempt to take advantage of the second as well.

A new type of spat collector, a modification of the common egg-crate filler, which provides a large amount of horizontal surface, was put into commercial use during the season. These apparently were highly successful and in every case obtained a most excellent catch of spat.

Preliminary experiments were made to determine at what tides larvae set most abundantly. It appears to be a common opinion that the water most favorable for setting is that retained in the dikes at low tide. By planting glass plates for periods of a few hours at a time, it was shown that less spat are caught at low tide than at any other time, that setting takes place primarily on the flood and high tides when the water is from 8 to 10 feet deep. Further tests will be made on this matter next season to clear it up more thoroughly.

An experimental study of the effect of temperature on the feeding of the Japanese oyster was made. It was found that the rate at which the oyster pumps water depends upon the degree of openness of the shells, that the shells are themselves dependent upon temperature and remain open widest at a temperature of approximately 20°C. The gills seem to pump most rapidly at a temperature above 25°. However, as the temperature rises obove 20°, the shells tend to close more and more, reducing the effectiveness of gill activity. More water is pumped by the average oyster at 20° than at any temperature either above or below. Apparently the Japanese oyster can pump water at a temperature as low as 2°C.

Oyster investigations in California.—At the request of the State Division of Fish and Game, H. C. McMillin has been detailed to assist the State authorities in developing the California oyster industry. At present extensive areas of inshore waters in California remain barren while the oysters are shipped in from the east coast or from the State of Washington. Small areas in San Francisco and Tomales Bay have been used for some time to hold imported oysters until they were marketed, but no attempts have been made until recently to cultivate and grow oyster seed.

Three species of oysters are available for use in California waters: The native oyster (*O. lurida*) found in natural beds in many small channels; the eastern oyster (*O. virginica*) transplanted from the Atlantic coast; and the seed of the Japanese oyster (*O. gigas*) imported

and grown to maturity in some bays. The seed of the last two species is accompanied by other forms which become troublesome pests, but with due precaution it is possible to cultivate these oysters safely in isolated areas.

The results of the investigation show that local conditions seem to warrant the development of the native oyster industry to the fullest extent. It is, however, imperative that the cultivation of oysters in any one bay be limited to a single species as far as possible. Thus the Japanese oyster can be grown on ground that is otherwise useless. Eastern oysters can be planted in San Francisco, and Tomales Bays, and Elkhorn Slough. In the latter locality seed oysters strung on ropes and suspended from floats grow twice as fast as in their normal habitat.

Small beds of the native oyster occur in the larger bays of northern California and in all bays and estuaries in southern California. They have been of little commercial value prior to the present investigation and the residents of the communities near the natural beds were unaware of their existence. During the past year extensive experiments have been undertaken, mostly in Humboldt Bay, and a method of culture by the use of artificial beds has been worked out. Small areas of barren tide flats in suitable locations are leveled, covered with gravel or shell, and surrounded by a board wall which holds about 2 inches of water on the bed at low tide. Seed oysters and shell are taken from the crowded natural reefs and transplanted to these beds where the size, shape, and meat content is greatly improved. It has also been demonstrated that the artificial beds catch a good crop of seed, and it is therefore probable that nearly 7,000 acres of tide lands in Humboldt Bay can be brought under intensive cultivation. Native oysters have, heretofore, consistently sold for the highest price of any oyster on the market, and the growers have rarely been able to fill their orders completely.

INVESTIGATIONS IN AQUICULTURE

Investigations in fish culture and related problems were carried on along much the same lines as in 1931. These investigations which are under the direction of Dr. H. S. Davis necessarily cover a wide field since they include studies relating to all phases of fish-cultural activities. While the work in the past has been primarily concerned with problems connected with hatchery operations increased attention is now being paid to the welfare of the fish after being liberated. This is fully as important as efficient methods of rearing fish since in order to utilize these fish to best advantage they must be surrounded by conditions conducive to their future development and well-being. It is apparent that in many cases much can be done to improve conditions in our lakes and streams so that they will be able to support much larger numbers of fish than at present. This is a problem to which relatively little attention has been paid in America, although in Great Britain and other European countries the importance of stream conditioning has long been recognized and notable success has attended its practical application, especially to trout streams. Stream improvement is a field that offers great possibilities for the future, but permanent progress must go hand in hand with years of painstaking research.

POND-FISH CULTURE

FAIRPORT STATION

The work of this station, which is under the direction of Dr. A. H. Wiebe, is devoted entirely to problems relating to pond culture. The main water supply is pumped from the Mississippi River into a reservoir whence it flows by gravity to the ponds. There is also a limited supply of well water which can be used in several of the smaller ponds. The entire pond system, comprising 24 dirt ponds of various sizes up to 3½ acres, is available for experimental work. In addition there are a number of concrete pools and indoor tanks and aquaria which are used for investigations requiring carefully controlled experiments.

Largemouth bass.—As in previous years, the pond experiments have been concerned primarily with largemouth bass although other species have received considerable attention. Owing to serious infestation of the brood bass with the tapeworm *Proteocephalus ambloplitis* the production of fry was much less than in previous years and it was consequently impossible to stock some of the ponds as heavily as planned.

Although experience has shown that the use of nursery ponds to which the bass fry can be removed and reared during the summer affords many advantages, there is increasing evidence that good results can frequently be obtained when the young are reared in ponds in which they were hatched. The greatest objection to this method is the fact that the fish are less under control, and there is no way of determining if the pond is properly stocked with fry. Nevertheless, very satisfactory results can be obtained with this method as shown by the results in a pond of 0.71 acres stocked May 4 with 3 male and 4 female largemouth bass, and 568 adult golden shiners for forage. The pond was given no further attention except that it was fertilized with 283 pounds of a mixture of dry sheep manure and superphosphate. This was applied in small amounts at intervals of about 10 days. The pond was drained September 8 and 7,376 fingerlings removed which is at the rate of 10,400 per acre. This is believed to be a very satisfactory yield since very little labor is required to produce fish by this method.

Smallmouth bass.—Although conditions at Fairport are quite different from those usually thought to be necessary for the culture of smallmouth bass a small stock of brood fish has been maintained for several years and the production of fingerlings has been fully equal to that of the largemouth. The fry and fingerlings are handled in the same way and reared in nursery ponds stocked with forage fish. In an attempt to determine the relative value of blackhead and blunt-nosed minnows for forage purposes two nursery ponds, with an area of 0.359 and 0.39 acres, respectively, were stocked with smallmouth fry at the rate of 25,000 per acre. Blackhead minnows were used for forage in one pond and blunt-nosed minnows in the other. The number of minnows in each pond was at the rate of 1,500 adults per acre. In all other respects the treatment of the two ponds was identical. When drained the first week in October the pond stocked with blackhead minnows yielded 12,282 fingerlings per acre, a survival of 49.3 percent, while the production in the one stocked with blunt-nosed minnows was at

the rate of 11,579 fingerlings per acre or a survival of 46.2 percent. The results indicate, as anticipated, that the blackhead and blunt-nosed minnows are equally valuable as forage fish.

Crappie and bluegill sunfish.—It has been found that crappie and bluegill sunfish make a very satisfactory combination, the production of crappie fingerlings being somewhat greater than when the pond is stocked with crappie alone. The young bluegills are evidently preyed upon by the crappie since only a comparatively small number of fingerlings of this species are produced under such conditions. This being the case it appeared that the production of bluegills might be increased by the use of minnows. Accordingly a pond was stocked with adult black crappie and bluegills as usual and in addition 12,000 blackhead minnows were placed in the pond to serve as forage. The yield from the pond was 19,164 crappie and 22,680 bluegills per acre, with a combined weight of 115 pounds. In 1931 the same combination without the blackhead minnows gave 20,562 crappie and 1,430 bluegills per acre. It is evident that the addition of forage minnows increased the yield of bluegill sunfish without materially affecting the number of crappie.

Effect of high-oxygen concentrations.—Dr. Wiebe has continued his experiments on the effects of high concentrations of dissolved oxygen, using brook and rainbow trout of various sizes. The results of these experiments are in full accord with those previously obtained with bass and other pond fish.

It was found that trout can withstand rapid changes from low to high concentrations of oxygen without injury. In some instances the fish were exposed to oxygen at from 10 to 20 pounds pressure for 46 hours without suffering any injurious effects. Even when suddenly transferred from water containing 51.8 parts per million of oxygen to water with an oxygen content of only 8.4 parts per million the fish showed only momentary signs of distress and no after effects were evident.

In another experiment brook and rainbow trout fingerlings were kept for 20 days in open tanks containing water supersaturated with oxygen. During this period the concentration of oxygen ranged from 21 to 33 parts per million and at no time was the saturation below 200 percent. The fish all survived the experiment and there was no evidence that they were affected adversely by the high-oxygen concentration. No case of gas bubbles or popeye was observed although the fish were watched carefully for these symptoms.

Experiments on the ability of fish to use oxygen at different hydrogen-ion concentrations show that largemouth and smallmouth black bass, green sunfish, crappie, yellow perch, and rainbow trout have the ability to extract oxygen from the water at low-oxygen tensions equally well over a wide range of hydrogen-ion concentrations. The bluegill sunfish has a somewhat narrower range of toleration while in the steel colored and blunt-nosed minnows the range is much more limited. Outside of the normal pH range of the species in question the lethal-oxygen tension is dependent in large measure on the initial amount of oxygen in solution.

Rate of digestion in bass.—A series of experiments by H. C. Markus to determine the rate of digestion in largemouth black bass at various temperatures gave some very interesting results. It was found that

the length of time required to digest minnows varied from 15 days at a temperature of 4° C. to 12 hours at 28° C. At 10° C. 92 hours were required for digestion while at 22° C. the food was completely digested after 16 to 22 hours. The fish would not take food satisfactorily at a temperature below 10° C., and it is apparent that bass require very little food at these low temperatures.

TISHOMINGO (OKLA.) STATION

Investigations on certain phases of pond culture were carried on at this station by O. Lloyd Meehean during the summer of 1932. The ponds at Tishomingo are all new and are supplied with water from a creek flowing through the station grounds.

Experiments with *Daphnia magna* showed that this organism can be reared successfully at the station if the temperature remains below 20° C. On the approach of hot weather the daphnia cultures deteriorated, and it was found impossible to keep them up during the summer. The daphnia were reared in concrete pools using dry sheep manure and superphosphate as a fertilizer. Some preliminary experiments on a small scale indicate that cottonseed meal will prove fully as valuable as sheep manure or soybean meal for rearing daphnia.

Routine collections of chemical and biological samples were made in the station ponds to determine as far as possible the conditions in each pond. The chemical data show that there is a large reservoir of carbon dioxide in a half-bound state which can be utilized for the growth of phytoplankton. The data also show the necessity for the control of the rooted aquatics in order to keep the carbon dioxide supply in an available condition. In most ponds the zoo-plankton was not abundant and in several cases it was very poor. In practically all instances the plankton decreased as the summer progressed and the amount of rooted vegetation increased. It is significant that in ponds with small amounts of vegetation Cladocera were abundant while in ponds with an abundant growth of rooted plants rotifers and Cyclops were the dominant organisms.

HACKETTSTOWN (N.J.) STATION

A cooperative experiment in rearing smallmouth black bass was carried on at the New Jersey State hatchery at Hackettstown by A. M. McGavock. The primary purpose of the experiment was to determine the most efficient and economical way to produce daphnia for feeding young bass. In one case the daphnia were cultured in a separate pond while in the other experiments the daphnia were grown in the same ponds as the fish. The latter method was used in a pond with an area 0.63 acre, which was fertilized with approximately 8,000 pounds of fresh horse and cow manure in addition to about 2 inches of trout excrement. As a result there was a very abundant growth of plankton and bottom organisms in the pond during the summer. The pond was stocked June 11 with bass fry at the rate of 25,000 per acre. It was drained September 8 and yielded 8,178 fingerlings averaging 6.48 grams in weight, a survival of 51.8 percent. This is a return of 12,990 fingerlings per acre. The total cost of labor and manure was $174.30 or $13.40 per thousand fish.

In another pond of approximately the same size daphnia were cultured from trout excrement produced by fifteen thousand 8- to 10-inch

fish which were wintered in the pond for 8 months. The pond was stocked June 14 with smallmouth fry at the rate of 22,130 per acre. When drained September 13, 5,480 fingerlings were removed with an average weight of 9,130 grams. This gives a return of 41 percent or 9,130 per acre. The total cost was entirely for labor at the rate of $50 per acre, or $5.47 per thousand fingerlings. Although the number of fish produced was somewhat smaller by this method the bass were larger and the cost of production much less.

In another experiment the daphnia were cultured in a separate pond, then flowed or netted over into the main pond. The total area including the daphnia pond was 0.69 acre. A total of 8,760 pounds of fresh horse and cow manure was used in addition to about 2 inches of trout excrement. The pond was stocked June 9 with smallmouth fry at the rate of 25,000 per acre. It was drained September 9 and yielded 8,609 fingerlings with an average weight of 3.23 grams. This gives a return of 49.8 percent at the rate of 12,475 fingerlings per acre. It should be noted, however, that these fish were only one half the size of those in the other ponds. The total cost of labor and manure was $12.40 per thousand fingerlings.

It is evident from these experiments that smallmouth bass fingerlings 3 to 4 inches long can be economically produced in heavily fertilized ponds without the use of forage minnows. They also indicate that the construction of separate ponds for the production of daphnia are not necessary. As a matter of fact the pond supplied with daphnia from another pond gave the poorest results of the three, but of course no general conclusion can be drawn from such a small number of experimental ponds.

TROUT CULTURE

Feeding experiments.—During the summer of 1932 feeding experiments were conducted at the Pittsford (Vt.) station under the direction of R. F. Lord as in previous years. Fish were also carried on experimental diets at the new hatchery at Leetown, W.Va., under the direction of E. W. Surber. Unlike the experiments at Pittsford those at Leetown will be continued through the winter. At Pittsford brook trout were used in most of the experiments with fingerlings, while at Leetown the majority of the experimental lots contained rainbow and brown trout. Experiments with yearling rainbow trout in out-door raceways were also carried on at Pittsford.

As in previous experiments, dry salmon-egg meal proved to be superior to any dry product now available for fish food. All diets containing this product gave a very rapid growth and the fish were exceptionally vigorous and well proportioned. As emphasized in previous reports they also exhibit the brilliant coloration characteristic of wild fish. These experiments show conclusively that the use of the better dry products in the diet of trout will give better results, both as regards growth and vigor, than can be obtained with any of the straight meat diets. Furthermore, they are in general more economical, since it requires a considerably smaller amount of food to produce the same growth when animal meals are included in the diet.

The results of the experiments with yearling rainbow trout agree closely with those obtained with fingerling brook trout. In most

cases a somewhat smaller amount of food was required to produce the same growth than with fingerlings, but this is probably caused by the fact that there is less waste in feeding larger fish. For the same reason larger amounts of dry foods can be included in the diets after the fish reach a length of 4 to 5 inches.

A number of experiments were undertaken at Leetown in cooperation with the Birdseye Laboratories, Gloucester, Mass., in feeding dry meals prepared by a special low-temperature process to rainbow trout fingerlings with and without the addition of fresh meat. Two dry meals were used in these experiments; one being composed of a mixture of meat meal, fish meal, and dried skim milk; the other had a similar composition except that it contained a considerable amount of dried beef liver. Each of these meals was fed to 3 lots of fish for over 8 months without the addition of any fresh meat or other food. One lot was fed meal which had been prepared before the experiments were started and stored in air. The second lot was fed meal which had been stored in carbon dioxide, while the third lot received meal prepared fresh each month and likewise stored in carbon dioxide. The losses were not excessive in any lot, but were noticeably less in those receiving meal stored in carbon dioxide. There was little difference in the mortality of the fish fed the meal stored in carbon dioxide from the beginning of the experiment and those receiving that prepared fresh each month. The growth of fish fed meal containing dry beef liver was slightly less, but there was very little difference in the mortality of the fish on the two meals.

Two lots of fish fed dry haddock roe prepared by the same process made a good growth with very little mortality. The growth on haddock roe was much superior to that obtained with the meals and the fish showed an even more brilliant coloration than those on a salmon-egg meal and liver diet.

It is evident from these experiments that trout are able to live indefinitely on dry foods when properly prepared. In no case, however, did the fish on an exclusively dry diet grow as rapidly as those fed salmon and liver. The haddock roe was not fed in combination with liver, but both of the meals produced a considerably greater growth when mixed with 20 to 40 percent of beef liver. Even then, however, the growth was inferior to that obtained with diets containing salmon-egg meal.

Selective breeding.—The work on selective breeding has been continued at Pittsford along the same lines as in previous years. So far the work has been confined to brook trout, but the results have been so encouraging that it is planned to expand it to include rainbow and brown trout. Most of the breeding work with these two species will be carried on at the Leetown station, where several thousand brook, rainbow, and brown trout are now being reared to maturity. During the fall of 1932 eggs were taken from 51 pairs of selected fish at Pittsford and the young will be kept separate until next fall when the inferior lots will be discarded. So far in these experiments special attention has been paid to rapidity of growth, vigor, and fecundity. The results attained have been remarkable considering the short time the work has been carried on.

Fingerlings reared in these experiments during the past summer represent the third generation of selected fish and many lots made a much greater growth than did the fingerlings from the general brood

stock such as were used in the feeding experiments. The lot making the greatest growth of those on experimental diets had an average individual weight of 6.09 grams on September 3, while one lot of selected fish on the same diet had an average weight of 12.7 grams on September 7. Another lot had an average weight of 12 grams and several lots averaged 10 grams or more. These results are the more striking when it is considered that the general brood stock has been improved by mass selection during this time, so that the average weight of fingerlings kept on a diet of beef liver during the summer has increased from 2.2 to 4.4 grams.

The increase in egg production as a result of selective breeding is equally gratifying. The average number of eggs produced at the end of the third summer (that is, by fish commonly known as 2-year-olds) was 958 in 1928 and 1,779 in 1932. These fish were selected as the best available fish of their age.

Additional data, showing the importance of heredity in determining the date at which trout spawn, was obtained during 1932. In one lot of fish containing thirty-eight 2-year-old females 33 were ready to spawn on November 8. The eggs from which these fish were hatched were taken November 9, 1929. In another lot containing 28 females, 25 fish were ripe November 8. The spawning date of the parents of these fish was November 8, 1929. In several other lots the results were nearly as striking.

Evidence was also obtained indicating that it will be possible to develop a strain of brook trout more resistant to furunculosis than the average fish of this species. Two lots of fish hatched in 1930 from mated pairs have shown a marked resistance to the disease, the percentage of survivors being much greater than in any other lots. Owing to the fact that it is very difficult to eradicate furunculosis after it has become established at a hatchery, the development of a resistant strain of fish offers one of the most promising means of combatting the disease.

Observations on recently liberated trout.—The belief appears to be increasing among anglers and others that trout reared at hatcheries are inferior to wild fish in several respects, and especially in their ability to forage for themselves. This may be true to a certain extent, but there is little definite information on which to base an opinion. In order to throw more light on this problem 100 yearling brook trout, averaging 7 to 8 inches in length, were liberated in a trout brook running through the grounds of the Pittsford station. These fish were marked by removal of a pelvic fin and liberated on August 18 shortly after the close of the fishing season. Up to the time of their liberation these fish had been held in one of the hatchery pools, with concrete sides and gravel bottom. They had been fed the regular hatchery diet of dry salmon eggs and liver, and were vigorous well-proportioned fish. Beginning 24 hours after the fish were liberated daily samples were taken on artificial flies and the stomachs preserved for study.

It was found that these trout took the fly with the same zest displayed by other fish taken in the course of the study and apparently gave the anglers as much "fight" as fish reared in natural surroundings. As in the case of the wild fish, it was found impossible to inveigle any of the hatchery trout into taking the fly on certain days, and it was concluded that they were not appreciably easier to capture than wild trout.

An examination of the stomach contents showed that in spite of the fact that these trout had been reared solely on artificial food they began to take natural food shortly after being liberated. The stomachs of fish caught the following day were filled with insects of various kinds showing that they were on the alert for natural food from the start. It was found that, in general, there was a slight increase in the amount of food eaten during the first 3 days but that after that there was little difference from day to day and that the amount of food taken was approximately the same as by wild fish. It would appear from this experiment that hatchery fish are fully able to forage for themselves as soon as liberated. Owing to the great importance of this problem further experiments along the same line will be undertaken in the near future.

Several experiments for the purpose of gaining information regarding the behavior of fingerling trout when first liberated were carried out at the Leetown station. Fingerling rainbow, brook, and brown trout were liberated in a small spring-fed stream and their movements carefully watched. The fish all showed a marked tendency to move in schools for several days at least after being liberated. A general tendency was noted for the fish to remain for some time in the pools in which they had been planted although there was a gradual dispersal along the stream. In this dispersal the rainbow trout moved more quickly downstream than upstream while the opposite was true of brook and brown trout.

In all cases the fish began taking food almost immediately after being liberated and examination of the stomach contents showed they were feeding on aquatic insects and crustacea. There was no evidence that the hatchery-reared fish were not able to capture these organisms as readily as wild trout. A marked increase in the brilliancy of the coloration was noticed within 2 weeks after the fish were liberated.

CALIFORNIA TROUT INVESTIGATIONS

Work on problems relating to the trout of California has been vigorously pursued during the past year. Early in July Dr. H. S. Davis and Dr. P. R. Needham were sent to California and in company with A. C. Taft made an extensive survey of the better fishing areas of the State with a view toward the development of a more intensive program of field investigations. At a conference held in San Francisco with the officials of the California Division of Fish and Game a new joint cooperative program was adopted which provides a comprehensive plan of study to be followed over a period of years. Dr. Davis returned to Washington in late August and the field staff now consists of Dr. Needham and Mr. Taft of this Bureau and two assistants, Leo Shapovalov and Francis Sumner, who were appointed to the work by the State.

Briefly, the program as now set up consists in attacking the trout problems of California from two angles; viz, a study of the trout and a study of their natural environment. The data obtained in these investigations will be utilized in the formulation of a scientific stocking policy for the waters of the State. The major projects selected for study are as follows:

1. A study of the species and races of trout to obtain as complete information as possible on the life history, habits, and ecological requirements.

2. The extent of natural propagation and its contribution toward stream populations.

3. Mortality of fish of various sizes when planted in the streams from the hatcheries.

4. Stream environmental studies to determine: (1) Seasonal abundance and distribution of fish foods; (2) the amount and kinds of shelter available for both young and adult trout; (3) effects of dams, falls, irrigation ditches, flumes, water wheels, etc.; and (4) chemical conditions such as gases in solution, hydrogen-ion concentration, and pollution.

For purposes of investigation the waters of the State may roughly be classified in three groups: (1) Southern region, (2) coastal region, and (3) Sierra region. The last-named region can be subdivided into a lower Sierra region, the waters of which are best adapted to rainbow and brown trout, and a high Sierra region containing waters best suited to golden and eastern brook trout.

The bulk of the work on streams of the coastal region has been carried on in Scott and Waddell Creeks in Santa Cruz County and to a lesser extent in the Klamath River and Alder and Garcia Creeks north of San Francisco. In the Sierra region the Truckee and Feather Rivers and Blackwood and Taylor Creeks near Lake Tahoe have received considerable attention. Next summer work is to be started on the golden trout of the high Sierras in the Cottonwood Lakes district near Mount Whitney. New studies will also be undertaken in the Merced and Tuolumne Rivers in the lower Sierra region. A knowledge of conditions in the trout waters of the State throughout the year is essential for the development of a scientific stocking policy and as far as possible seasonal studies will be carried on in all these regions.

Much information has already been obtained from studies of sea-run steelhead trout based on marking experiments with young fish and returned spawners and also from periodical samples taken in several coastal streams. In October 40,000 fingerling rainbow trout from two different lots of fish were marked and released into the Truckee River for studies on their migratory habits. The experimental ponds constructed on Hot Creek in Mono County were operated during the summer for the study of growth rates and mortalities of fingerling rainbow trout on natural food.

Quantitative food samples taken in Sierra streams near Lake Tahoe have shown riffle areas to average approximately 137 pounds of food per acre. Waddell Creek, a coastal stream, was found to produce nearly the same amount giving an average of 132 pounds per acre. The dominant food organisms in all stream bottom samples taken thus far have been caddis larvae and pupae, mayfly nymphs, and and aquatic Diptera. The lagoons at the mouths of coastal streams have been found to be exceptionally rich in both amphipod and isopod crustaceans and consequently afford fine feeding grounds for young trout.

FISH DISEASES

Routine investigations have been carried on in connection with several trout diseases whenever there was an opportunity. Although most of the common trout diseases have been studied by various

investigators there is still much to be learned regarding even the best-known disease which will be of great assistance in developing more effective methods of control. Requests for the diagnosis of diseased fish are constantly increasing and considerable time is spent in the routine examination of specimens sent to the Washington office for this purpose. The constantly increasing demand for large trout for stocking purposes has resulted in a more complete realization of the importance of disease in fish-cultural practice. The control of disease is now recognized as one of the most important problems confronting the fish culturist, since the output of his hatchery depends to a very large degree on his success in keeping the fish free from infection.

In view of the importance of this problem a program has been worked out whereby members of the aquicultural staff make occasional visits to hatcheries located within a reasonable distance, for the purpose of detecting the presence of disease and also to furnish advice and assistance in every way possible. Unfortunately, owing to decreased appropriations it was necessary to practically discontinue this service after several months, but enough was accomplished in the brief time it was in operation to demonstrate clearly its value in increasing hatchery production.

Dr. Frederic F. Fish spent some time at the Fairport (Iowa) station investigating the bass tapeworm with which the brood fish have become heavily infested. It is evident that this parasite constitutes a problem of major importance in bass culture since, when abundant, it seriously interferes with reproduction and may cause practical sterilization of the brood fish. It is believed, however, that by exercising proper precautions it will be possible to prevent the young bass from being infected and in this way a brood stock can be built up which will be free from the parasite. It is very evident that under present conditions it is impractical to rely on wild fish for brood stock and that the future success of bass culture depends on hatchery-reared brood fish free from parasites and disease.

Experiments are being conducted with the object of developing a method of treating trout in pools for external parasites. At present when fish in pools contract gill disease or become infected with protozoan parasites it is necessary to remove them for treatment. It is believed that by the use of very dilute solutions it will be possible to cure the fish while still in the pools and thus avoid the injurious effects of handling which usually result in considerable mortality. If a successful method of treating the fish can be worked out it will remove the most serious objection to the use of pools or raceways for rearing small fingerlings.

COOPERATIVE STUDIES OF THE NUTRITIONAL REQUIREMENTS OF TROUT

During the past summer an agreement was executed between the United States Bureau of Fisheries, the New York State Conservation Department, and the New York College of Agriculture at Cornell University for the purpose of conducting on a cooperative basis experimental studies in fish culture relating especially to fundamental problems of nutrition and physiology of fishes. Complementing, and to a certain degree paralleling, studies of fish-feeding conducted at the Bureau's experimental fish-culture stations, the new undertaking

has been designed to deal particularly with the digestibility of various nutrients by trout, the vitamin requirements essential to an economical and successful ration, and with enzymotic and other physiological and metabolism studies.

These investigations, under the direction of Dr. C. M. McCay of the animal nutritional laboratory at Cornell University, are being conducted in the Bureau's hatchery near Cortland, N.Y. The Bureau is furnishing suitable hatchery facilities, including the hatchery building and such rearing ponds as are needed, the stock of eggs, and part of the feeds necessary for rearing fish. The New York State Conservation Department is providing the necessary funds for the compensation of the technical assistants involved in this work and for special apparatus and feeds needed for the experiments. The State College of Agriculture provides necessary laboratory facilities at Cornell University for experimental work and analyses not readily conducted on the hatchery premises.

Preliminary feeding experiments with brook trout were started at the Cortland experimental hatchery during the month of August and are being run by A. V. Tunison, who was formerly in charge of similar work in Connecticut. Because of the late start of this work, it seemed judicious to limit the scope of experimentation during the balance of the growing season chiefly to a comparative study of the growth of brook-trout fingerlings fed diets composed of various dry foods in conjunction with various raw meats.

Between 30 and 40 different diets were chosen for these preliminary studies. These were composed chiefly of the dry foods which proved to be most promising during the past five years of similar research carried on by Dr. McCay in Connecticut. However, during the present studies the tests were made more rigid than formerly by including only foodstuffs of which the origin and processing are known. A series of dry skim milks made by different methods has been included in the testing.

Certain tentative conclusions may be drawn from the first four months of this work. The better grades of dry skim milk have all proved satisfactory when fed in a mixture composed of equal parts of prime cottonseed meal and fresh meat. Dry buttermilk can replace the dry skim milk and peanut meal may replace the cottonseed meal without affecting the growth of the experimental animals. The fresh meats used in these diets were sheep liver, sheep heart, and beef spleen. Lots of 200 fingerling brook trout grew equally well on these combinations.

No significant difference was found in the growth curves obtained from fingerling brook trout fed dry foods mixed in a 2 to 1 proportion with fresh sheep plucks and trout fed entirely sheep plucks.

Confirmation was made of Dr. McCay's previous findings that trout cannot be maintained indefinitely upon a diet supplemented by meat, such as commercial scrap meat, dried at the usual high temperature and exposed in air in the course of drying. Confirmation was likewise made of the fact that dry skim milk or dry buttermilk will not promote normal growth of brook trout for a period exceeding 14 to 16 weeks.

Good growth was obtained with fingerling brook trout that were fed daily dry feed mixtures containing dry skim milk, 2 parts; cottonseed meal, 2 parts; and whitefish meal, 2 parts, with supplements

of raw sheep plucks 1 part fed at weekly intervals. Thus far, in a period of over 3 months, the growth of the trout fed fresh meat weekly was equal to that obtained by feeding the same dry diet containing an equivalent amount of meat fed daily. By weighing the feed every effort was made to allow the same amount of raw meat to both groups. Contrary to the common belief, no untoward effects were noticeable in brook-trout fingerlings fed for 16 weeks on a straight raw-spleen diet.

Several experiments have not progressed sufficiently at the present time to justify drawing conclusions. Among the incompleted experiments are grouped the comparative growth of brook- rainbow- and brown-trout fingerlings on a standard adequate diet, and the possible relationship existing between underfeeding and the resulting slow growth upon the firmness of trout flesh. Experiments are also in progress to determine if the melting point of a fat determines its degree of utilization by fish.

The use of formalin-preserved meats as substitutes for fresh meat in localities where the latter is not easily available is also under investigation. Fresh ground sheep plucks preserved in 1 percent formaldehyde seem to be as effective as fresh meat in supplementing dry diets.

LIMNOLOGICAL INVESTIGATIONS IN THE ROCKY MOUNTAIN REGION IN THE INTEREST OF FISH STOCKING

During the season of 1932 investigations of the waters of this region under the direction of Dr. A. S. Hazzard were continued in the interest of wiser and more economical distribution of the output of Federal hatcheries. Cooperation in this problem was also extended to the States of Montana, Idaho, and Utah, although most of the work was concentrated in the national parks and national forests. The extension of highway travel and the rapid increase in the number of anglers have necessitated radical changes in methods of planting and have demonstrated the necessity for systematic stocking based upon accurate knowledge of conditions for fish life existing in the more accessible lakes and streams.

Since the Bureau's responsibility for maintaining and improving angling is definitely indicated in the waters of the national parks and national forests, limnological investigations have been concentrated in these areas.

SURVEYS IN THE NATIONAL PARKS AND NATIONAL FORESTS

Grand Teton Park.—A program of biological surveys of the national parks was initiated in 1931 by a study of the lakes and streams of Grand Teton Park, Wyo. In this newly established park little stocking had been done prior to 1931. This, together with increased fishing, resulted in a condition of depletion which called for immediate attention. Survey of these waters revealed marked scarcity of suitable spawning grounds which explained the rapid deterioration in angling resulting from heavy fishing and inadequate planting. Rearing ponds were constructed here during the summer of 1932 and plantings of good-sized fingerlings were made that season in accordance with the findings of the survey relative to suitability for various species and carrying capacity as determined from these studies. It will of course require several years for the results of the stocking

plan to become apparent. Much valuable information is anticipated which should assist in planting lakes of these types.

During September 1932 an opportunity was afforded to complete the survey of Jackson Lake, a United States reclamation project. Although not included within its present boundaries, this reservoir is logically associated through drainage relations with the waters of Teton Park. Studies of the chemistry and food supply this season supplement the data gathered during the summer of 1931.

Glacier National Park.—A biological survey of this, the third largest national park, was begun during the season of 1932. Glacier Park includes 1,534 square miles of picturesque mountain scenery in northwestern Montana. In this area are several hundred lakes and numerous streams varying greatly in altitude, size, depth, temperature, chemistry, and food supply. Under such conditions it might be expected that many problems should arise from attempts to properly stock these waters, the great majority of which were originally barren of all fish life. Some have remained so in spite of attempts to introduce various species. Efforts to improve certain streams by planting have been unsuccessful. In one lake fishing is unsurpassed; in another plantings have met with poor success. Stocking records show that encouragement of a certain species in one lake has not increased its numbers perceptibly while another species has become abundant chiefly through natural spawning. The most suitable species for the numerous high, cold lakes is an important problem which received much attention.

A party of three biologists began survey work in Glacier Park June 5 and continued in the field until September 13. The United States Fisheries station at Glacier Park was made the base of operations. Thirty-two streams, 35 lakes and their principal tributaries, constituting about one third of the accessible waters of the park, were examined during this period. Few of these waters can be reached by road so that much of the work had to be accomplished using pack and saddle horses. All equipment was selected with this in view and proved to be very satisfactory.

The National Park Service, represented by Supt. E. T. Scoyen and his assistants, aided the work materially by supplying information and by loaning equipment.

The facts available from the study were used in assigning fish for the waters of the park this season. Although limited time and lack of equipment prevented the analysis of samples and all data in the field, it was found possible to offer some definite suggestions for planting in 1932.

In the study of streams information concerning the following was collected: Average width and depth, volume, velocity, gradient, color and turbidity, fluctuation in level, temperature, bottom composition, condition of pools, location and height of barriers to fish movement, character of watershed, presence of springs, character of tributary streams, hydrogen-ion concentration, alkalinity, type and abundance of aquatic vegetation, relative abundance of primary fish foods, relative abundance and size of game and forage fish, conditions for natural spawning and evidence of its success, presence of fish enemies and parasites and the quality and intensity of the fishing.

Survey of lakes included observation and record of the following: Altitude, approximate area, length of shore line, character of watershed, fluctuation in water level, type of shore and bottom, location

and extent of shoal areas, sufficient soundings to indicate the type, inlet and outlet streams, color and transparency, temperature at the surface and at intervals to the bottom, hydrogen-ion concentration, quantity of oxygen and carbon dioxide, alkalinity as indicated by carbonates and bicarbonates, type and abundance of vegetation, relative abundance of fish food, relative abundance and size of game and forage fish, presence of spawning grounds and evidence of natural reproduction and, finally, the quality and intensity of the fishing.

In addition to this routine examination employed in single studies of lakes and streams, seasonal studies were made at monthly intervals on five typical lakes east of the Continental Divide. At selected stations on these lakes the following data were secured: Transparency, temperature at regular intervals from surface to bottom, chemical analyses, vertical plankton hauls, samples of the bottom fauna and of the fish for food and growth studies. The level and temperature of several principal streams were also recorded throughout the season.

Collections of aquatic plants and principal fish foods were secured from all waters studied and whenever possible fish were collected for the purpose of food and growth determination. Certain waters offering special problems were studied more in detail with the object of determining the reason for marked success or failure in planting. The results of natural spawning were deemed a problem of first importance and every effort was made to secure as much information as possible on this subject.

At the close of field work operations were transferred to the Bureau's laboratories at the University of Utah in Salt Lake City, where a study of the data collected is in progress. The results of this survey will appear in a publication by the Bureau when funds for this purpose are available.

Wasatch National Forest investigation.—Owing to lack of funds further limnological studies in the Wasatch National Forest, Utah, could not be pursued. The data collected here during the seasons of 1930 and 1931 have been studied, and a stocking plan inaugurated for the principal waters of this forest. This plan was followed insofar as cooperation of the Bureau, the United States Forest Service, and the Utah Fish and Game Department could be effected. Although results of this plan will not be apparent for several years, one outstanding success of the survey's recommendations should be mentioned. One of the principal, heavily fished lakes of the Wasatch was found to be overstocked with poor-conditioned fish at the time of the survey. It was recommended that no more trout be planted here until August 1932, when a limited number of legal fish should be released to replace those removed earlier in the season. This plan was followed and resulted in a marked improvement in the condition of the trout and good fishing prevailed throughout the summer. It is believed that this result indicates the success which can be attained by properly balancing stocking against carrying capacity.

OTHER LIMNOLOGICAL STUDIES

Spring Creek investigation.—At the request of the Weber County Sportsmen's Association, an examination of Spring Creek, Utah, was made to determine if food had recovered sufficiently to warrant

stocking this year. Pollution from a pea vinery in 1930 had killed many trout in a section of the stream.

A study of the food organisms was made above and below the point of pollution. It was found that conditions were approximately the same in both sections of the stream except that may fly and stone fly nymphs averaged much smaller in size in the lower section. Large shrimp were common in both parts of the stream. From these observations it was decided that recovery was practically complete and that stocking with a limited number of trout might be safely resumed.

Georgetown Lake.—At the request of the Montana Fish and Game Commission, a brief investigation was made concerning the mortality suffered by adult cutthroat trout and grayling in Georgetown Lake. The seriousness of the annual loss in fish at this important spawn-collecting station may be judged from estimates which run from 2,500 to 15,000 adult trout and grayling. The cause of this mortality, which has steadily increased during the last three years, has been attributed to a number of conditions which have been eliminated with no resulting improvement.

Other duties prevented more than a preliminary investigation at Georgetown Lake. Macroscopic examination of freshly dead specimens were made. Approximately half of the trout appeared normal except that the peritoneum was blotched and speckled with bloody areas. Presence of food in the stomach and considerable fat on the viscera indicated sudden death. The remaining trout and all grayling examined exhibited reddened areas or vertical red scratches just behind the pectoral fin and in some cases posterior to the dorsal or near the vent which permeated the tissues to a considerable depth. Sex determination indicated that the loss at this time appeared to be almost wholly confined to the females.

The presence of bacterial infection probably aggravated by crowding and high water temperatures was suggested. A thorough study throughout the following season was recommended.

Payette Lake.—At the request of the Idaho Fish and Game Department, a brief limnological study was made of Payette Lake during October to determine the best planting policy for these waters. Consistent stocking with good sized fingerling trout during past years had not shown the anticipated improvement in fishing.

The usual procedure for study was followed which indicated that Payette Lake is deficient in food production presumably due to limited shoal areas, scarcity of aquatic vegetation, unproductive bottom, and lime deficiency. It was recommended that recently enacted measures protecting the spawning grounds of the principal fishes (redfish, redside cutthroat, and whitefish) be continued and that the redfish and cutthroat be encouraged by artificial propagation. The proposed introduction of bass and mackinaw was condemned in view of the food scarcity and danger to the valuable native fishes.

MUSSEL INVESTIGATIONS AND POLLUTION STUDIES IN INTERIOR WATERS

The various activities carried forward by the staff headquartered at the University of Missouri, under the direction of Dr. M. M. Ellis, have been grouped under two headings, namely, pollution and mussel propagation studies, largely as a matter of mechanical convenience.

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In actual work the two sets of operations have been intimately associated, each serving to further the interest of the other, so that the distinction is less real than the headings would indicate.

POLLUTION STUDIES IN THE MISSISSIPPI

In cooperation with the Corps of Engineers, United States War Department, the studies of the Mississippi River and its tributaries with particular reference with fisheries problems as influenced by both pollution and navigation have been continued during 1932. Three portions of the Mississippi River were given particular attention.

A survey of the Hastings Pool, that portion of the Mississippi River impounded by the Hastings Dam and lying roughly between Hastings and Minneapolis, Minn., was made with special attention to the effects of the polluted waters held in this pool, on the lateral and connecting sloughs and lakes. Detailed plankton and chemical studies were made and a condensed report on this investigation is now in the hands of the War Department and United States district attorney for the Minneapolis district. These data will also be included in the forthcoming report on the Mississippi River.

Using the Engineer boat yards at Keokuk, Iowa, as headquarters, observations on Lake Keokuk were continued at various times through the spring, fall, and winter of 1932 in addition to the intensive studies of this lake during the months of May, June, and July. The effects of pollution, silt, and sudden changes in water level incident to the run-off from storms, on water conditions, fish food, and the bottom fauna were the major contacts. From these studies together with those of the two previous summers a very complete picture of the chemical, physical, and biological conditions now obtaining in this artifical river lake is now available not only for the Mississsippi problems but as a standard for the evaluation of fisheries conditions in other such river lakes. The action of silt on the basic fish food, plankton, has been given special consideration throughout these studies and correlations with the chemical and physical changes in the water have been made. These findings as part of the Mississippi River report are now being put in final form and soon will be available for publication.

The United States Fisheries laboratory, quarterboat *No. 348*, and appended boats, after serving as a base of operations for the studies at Lake Keokuk were moved down river to Grafton, Ill., early in August, and a survey of the Mississippi River between Grafton, Ill., and Hannibal, Mo., was completed. This portion of the river had been given little attention in the previous pollution work carried forward by the unit. The Grafton-Hannibal survey occupied some 5 weeks during August and the first of September.

Summarizing all of the Mississippi River studies which are being united into a report covering the Mississippi River from Minneapolis to Cairo, the Ohio from Cairo to Evansville, Ind., and the Tennessee from Paducah, Ky., to the Hiwassee River above Chattanooga, the enormous damage to fisheries and fishery industries by uncontrolled erosion is outstanding. Operating with the silt are municipal sewage and industrial wastes both greatly increasing the pollution hazards. Data obtained throughout this survey show that the uncontrolled introduction of silt into these streams has tremendously increased the

areas disturbed by the major pollution centers such as the Minneapolis-St. Paul, Davenport-Rock Island, and St. Louis districts, since such silt makes it impossible for the streams to rid themselves of the huge volumes of various organic wastes which are now being poured into these waters. Since the actual volume of municipal wastes has increased so enormously during the past few years, and as it is now coupled with silt the general pollution problem has become so serious in the Mississippi River and tributary streams that the aquatic life has been practically reduced to those few undesirable forms capable of surviving in highly polluted water in large stretches of these streams and the combined pollution is spreading with amazing rapidity.

MINE POLLUTION IN COEUR D'ALENE DISTRICT IN IDAHO

In cooperation with the Coeur d'Alene River and Lake Commission appointed by the State of Idaho to investigate mine pollution conditions in the Coeur d'Alene district, Dr. Ellis and party conducted a field survey in this district during the month of July. Various samples of material were forwarded to the Columbia laboratory where detailed physiological and biochemical studies were made. A report on these investigations has been sent to the State of Idaho, and the findings may be summarized briefly as follows:

1. The mine wastes collectively have killed out practically all forms of aquatic life for 50 miles in the Coeur d'Alene River.
2. The destructive action of these mine wastes is due to the enormous bulk of finely powdered rock which has literally smothered every living thing on the stream bed, and to the production of toxic substances (chiefly lead and zinc compounds) from the mine wastes which are deposited during high water on the flats along the stream and from which toxic products reenter the stream following high water or rain.
3. The pollution has extended well across Coeur d'Alene Lake out through Spokane River and into the State of Washington, but has not yet become critical beyond Coeur d'Alene Lake.
4. The polluted waters of Coeur d'Alene River were found to be highly toxic to both native fish and various plankton organisms.
5. The experimental work with the various mine wastes and chemicals used in the mining processes demonstrated the toxicity of several of these substances to aquatic life, fish developing typical lead-poisoning symptoms when exposed to combinations of these mine wastes.
6. Studies made in Canada at similar mines and mills operating under similar conditions show that these polluting materials can be handled by the mines and the stream pollution eliminated, as a method of disposal of mine wastes has already been worked out and is now in satisfactory operation in Canada.

LABORATORY STUDIES OF POLLUTION

In connection with all of the above investigations over 5,000 samples of water carrying erosion silt have been studied during the past year. These samples were collected from important stations in various parts of the Mississippi Valley, and in Idaho, Texas, Washington, and British Columbia. As a result of these studies the action of silt on the chemical composition of river waters, the effect of

silt in screening and sorting light in river and lake waters, and the changes in water temperature, dissolved gases, and other chemical reactions of the river waters as a result of presence of suspended silt have been determined. A report on the technical aspects of this problem and application of these technical facts to the economic fisheries problems produced by silt is now in preparation.

In the course of the pollution studies methods for use of the plankton animals as "index" or "test" animals in pollution studies have been worked out. Both because of their economic importance as one of the basic links in the food chain of most aquatic animals and because of their physiological reactions, plankton have been found to be very suitable for pollution tests. A discussion and description of these methods is to appear shortly in a technical journal.

In connection with both the Idaho pollution studies and the general survey of the Mississippi River and its tributaries, large series of experiments dealing with the effect of lead, zinc, ammonia, sulphur, and various specific substances present in particular types of industrial wastes have been made on fishes, fresh-water mussels, plankton, and other aquatic animals. These tests have provided basic information for the evaluation of pollution findings not only in the specific cases involved but for future investigations.

MUSSEL PROPAGATION

During the year 1932 a large-scale experiment carrying with it various appended studies on the growth, survival, feeding, and general health of fresh-water mussels, both juvenile and adult, in confined areas where the particular environment can be specifically controlled, was begun at the Fort Worth station of the United States Bureau of Fisheries. Raceways having various types of bottoms over which water of different depths is maintained have been planted with young and adult mussels of various species. Not only have the economic species of Texas been planted in these raceways, but shipments of important species from Indiana, Iowa, Arkansas, Illinois, and Missouri have also been made to Fort Worth.

The particular objective is the determination of the maximum number of fresh-water mussels which may be raised successfully in a given area by artificial propagation, artificial planting, and from selected brood stock. By means of special apparatus continuous series of observations on water conditions, food requirements, growth, and activities of these mussels are being obtained daily by an investigator detailed to this laboratory. Since each mussel is marked, the relative death rate of the various species and state of health and growth of each individual are being checked from week to week. At intervals the raceways are emptied of water and the mussel population inspected directly.

As this experiment must be continued over a period of 2 to 3 years before final results can be stated only an advance report can be given at the present time. Gratifying results, however, have been obtained in the growth, crowding, and feeding tests, and these findings at present seem to indicate that a very large number of mussels may be successfully crowded into a small space if proper water and food conditions are maintained. At present over 6,000 adult mussels are under observation in these raceways as well as various plantings of young.

In connection with the Fort Worth propagation experiment, feeding and food requirement experiments are being carried on continuously in the Columbia (Mo.) laboratories. One set of experiments recently completed has shown that fresh-water mussels can live for a period of 18 months or longer without food, but that during starvation periods serious changes in shell and soft parts take place. Through the studies of the utilization of various food constituents by the mussels, data have already been collected showing that the mussels may be fed various inexpensive foods successfully and their health and activity greatly improved. At present a series of tests are going forward dealing with the requirements for shell production, and it has been found that a certain diet greatly increases the growth of shell and the deposit of lime in the shell. These experiments have, of course, immediate practical value in accounting for differences in shell quality in different streams and are to be applied this spring to the feeding of mussels in captivity in the Fort Worth raceways.

In connection with the artificial propagation work, the factors regulating the spawning and production of glochidia in the gravid female are in progress. One of the difficulties in handling gravid mussels of certain species is a tendency to abort the unripe glochidia. Factors surrounding these complexes are now under investigation.

Mussels population and growth studies in various of the major shell-producing tributaries of the Mississippi have been completed during the current year and the data are being tabulated and plotted as rapidly as possible. Over 12,000 shells have been examined; and the relation between chemical composition of the water pollution and erosion silt have been correlated with the population, growth, and pollution studies. From these studies it is now well established that, with the exception of the paper shells and certain other undesirable species of mussels, the great majority of our fresh-water mussels are not maintaining a replacement population; that is, the various commercial species of mussels are falling behind in annual replacement even in the undisturbed and closed streams as a result of the increasing pollution and erosion hazards. In the main, there has been little successful replacement of fresh-water mussels in the Mississippi Valley, except in a few restricted local areas, since production of the year class of 1925.

In connection with all of the mussel studies various observations on the life history, biology, and ecology of various mussel species have been made. One in particular may be mentioned, namely, the very curious spawning of the Arkansas fan shell *Cyprogena alberti* (Conrad) which has been worked out in the laboratory for the first time.

INDEPENDENT ACTIVITIES OF FISHERY BIOLOGICAL LABORATORIES

WOODS HOLE, MASS.

The biological station at Woods Hole continued to serve the needs of Bureau investigators during the spring and summer of 1932, though lack of funds prevented the furnishing of facilities to guest investigators as had been, up to this time, the long-established policy of the bureau.

Among the activities at the laboratory were: Studies on the physiology of the oyster and control of starfish by Dr. P. S. Galtsoff and

assistants; investigation of survival of mackerel larvae on the offshore spawning grounds by O. E. Sette, with the *Albatross II* basing at the station; study of the physiology of year-mark formation on fish scales by R. A. Nesbit; experimental rearing of fish larvae by Louella E. Cable; study of the effects of temperature on the incubation of mackerel eggs by Leonard G. Worley; and study of the abundance and growth of young scup, sea bass, and squeteague in the Woods Hole region by Prof. A. E. Parr of the Bingham Oceanographic Foundation. The new station tender, *Phalarope II*, proved admirably fitted to the young-fish trawling and other services at the station.

BEAUFORT, N.C.

Research.—Operation of the Beaufort laboratory was continued throughout the year under the direction of Dr. H. F. Prytherch and furnished facilities for the study of fishery problems of the South Atlantic region. The chief investigations conducted here at present by the Bureau's staff, as reported elsewhere, deal with the application of science to oyster farming in southern waters, the development of new methods of opening oysters, the reproduction and distribution of shrimp, and the propagation of the diamondback terrapin. Laboratory facilities for marine research have been furnished to 16 independent research workers from other institutions who have engaged in the following studies: Dr. H. V. Wilson, University of North Carolina, development of sponges; Dr. Ezda Deviney, Florida State College for Women, regeneration in Ascidians; Dr. O. W. Hyman, University of Tennessee, larval development of the stone crab; Dr. Elinor H. Behre, Louisiana State University, effect of environmental changes on chromatophores of some invertebrates; Dr. W. C. George, University of North Carolina, chordate blood; J. Paul Reynolds, Johns Hopkins University, marine fauna; Mabel L. Bacon, University of North Carolina, air bladder and ear of certain fishes; Dr. Hoyt S. Hopkins, New York University, growth rate, distribution of catalase in bivalve mollusks; Dr. Irving E. Gray, Duke University, swim bladder of fishes; Henry Vander Schalie, University of Michigan, faunal relations of Naiades to brackish water; Dr. Bert Cunningham, Duke University, embryonic development of terrapin; Dr. Leon C. Chesley, Duke University, digestion in marine fishes; Joseph M. Odiorne, Harvard University, color changes in Fundulus; F. R. Brown, University of North Carolina, distribution of echinoderms; Dr. Everett I. Evans, United States Department of Agriculture, physiology of sex in mammals; J. P. Givler, North Carolina College for Women, embryology of the alligator.

The facilities of the station were also utilized by the United States Chemical Warfare Service for tests of wood preservatives and by the Bureau's Division of Fishery Industries for experiments with treated rope under various tidal conditions. Cooperative tests were made with the Woolsey Paint Co. in respect to antifouling and protective value of copper paints and with the Colvulc Rubber Co. for similar experiments with rubber paint products.

Terrapin culture.—A new record in the propagation of the diamondback terrapin was established in the rearing of the 1931–32 brood which exceeded by over 95 percent the number grown and distributed by this station during previous years. During the period from May 7

to 25, 1932, a total of 11,086 young of the diamondback terrapin were distributed in the waters of North Carolina by the Bureau in cooperation with the State Department of Conservation and Development. In recent years the propagation of the terrapin has met with increasing success so that it has been possible to release consequential numbers of young each spring. The output of the Beaufort station hatchery since 1928 has been as follows: 1928, 5,388; 1929, 5,855; 1930, 5,778; 1931, 5,500; and 1932, 11,086. Previous to liberation the shell of the terrapin is marked or punctured in order that those released by the hatchery may be identified later in the commercial catches. Many of those distributed previously have been caught by fishermen in this region which indicates that such propagation operations are effective in increasing the supply of these animals.

The destruction of young by certain diseases, particularly that known as "sore tail", has been reduced to a large extent by chemical treatment. By regularly sterilizing the rearing troughs with strong salt brine and using therein small pieces of metallic copper the mortality of young has been limited to less than 9 percent of the total brood for 1931–32. The propagation of this species will be conducted in the future by the Division of Fish Culture, and more extensive distribution of the young terrapin will be made throughout the South Atlantic region.

APPROPRIATIONS

During the fiscal year ending June 30, 1932, $322,500 was provided for the scientific work of the Division. For the remaining half of the year appropriations available for the fiscal year 1933 totaling approximately $222,000 were available. These figures represent the combined appropriations from various accounts, except funds spent for vessel operations in connection with scientific work, which totaled $14,000 additional. This represents a reduction of 31 percent over the previous year in the funds appropriated for inquiry and has necessitated in addition to the curtailment of all activities and abandonment of some, the serious reduction of fishery investigations in the North Atlantic offshore area by the decommissioning of the Fisheries research steamer *Albatross II*. Thus, the Bureau is left with no means whatever of conducting certain types of investigations on the fishing grounds where the most important marine fisheries of the United States are prosecuted.

The funds were allotted in the various sections of the country as follows: For fishery investigations in the North and Middle Atlantic area, 21 percent; for the South Atlantic and Gulf area, 16 percent; for the Great Lakes, 9 percent; for the Pacific coast and Alaska, 21 percent; for the Mississippi and Gulf drainage, exclusive of game fish propagation studies, 6 percent; for studies on the conservation of fish by means of screens and ladders, 3 percent; unallocated as to geographic districts, funds for the investigation of cultivation of oysters and shellfish amounted to 4 percent, and for studies in the interest of fish culture and stocking of game fishes, 17 percent.

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